JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. CIV. DECEMBER, 1877. No. 6.

THE Franklin Institute is not responsible, as a body, for the statements and opinions advanced by contributors to the JOURNAL.

Franklin Institute.

HALL OF THE INSTITUTE, Nov. 21st, 1877.

The stated meeting was called to order at 8 o'clock P. M., Vice-President Chas. S. Close in the chair.

There were present 111 members and 25 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting the following donations were made to the Library:

Kanton Bern. Statistik eines Theiles der kantonalen Bauverwaltung, 1875. From S. L. Smedley.

Tables and Formulæ useful in surveying, geodesy and practical astronomy. Washington, 1873.

Report on the Defences of Washington to the Chief of Engineers, U. S. A. By J. G. Barnard. Washington, 1871.

Report on the fabrication of iron for defensive purposes. Washington, 1871. With Supplement. Washington, 1872.

Report upon the physics and hydraulics of the Mississippi River. By Humphrey & Abbot. Washington, 1876.

Practical tables in meteorology and hypsometry. By R. S. Williamson. New York, 1868.

On the use of the barometer on surveys and reconnoissances. By R. S. Williamson. New York, 1868.

Report on the effects of firing with heavy ordnance from casemate embrasures. By J. G. Totten. Washington, 1857.

Treatise on the various elements of stability in the well proportioned arch. By D. P. Woodbury. New York, 1858.

Official report to the U. S. Eng. Dep't of the siege and reduction of Fort Pulaski, Georgia. By Q. A. Gillmore. New York, 1862.

Sustaining Walls. By D. P. Woodbury. Washington, 1854.

From the Chief of Engineers, U. S. A.

Report on the meteorological, magnetic and other observatories of the Dominion of Canada, for 1876. Ottawa, 1877. From the Meteorological Office.

Pottery and porcelain. Hand book for the use of visitors in the Museum of Art. New York, 1875. From E. Hiltebrand.

Journal of the Royal Geographical Society, Vol. 46, 1876. From the Society.

Tables for determination of Minerals. By Persifor Frazer, Jr. From J. B. Lippincott & Co., Publishers.

Annual report of the Secretary of the Navy, for 1876. Washington, 1876. From the Secretary.

English Patent Specifications and Drawings for 1876 (No. 1, Jan. 1, to No. 4800, Dec. 12). From the British Patent Office.

Bulletins of the United States National Museum. No. 7. Contributions to the natural history of Hawaiian and Fanning Islands and Lower California. By Thos. H. Streets. Washington, 1877.

No. 8. Index to the names which have been applied to the subdivisions of the class Brachiopoda. By W. H. Dall. Washington, 1877.

No. 9. Contributions to North American Ichthyology. No. 1, by D. S. Jordan. Washington, 1877.

Bulletin of the United States Geological and Geographical Survey of Territories, Vol. 3, No. 4. Washington, Aug., 15, 1877.

Synopsis of the Flora of Colorado. By Thos. C. Porter and J. M. Coulter. Washington, Mar. 28, 1874.

Rules and list of Members of the Royal Society of New South Wales, 1877.

Birds of the Northwest. By E. Coues. Washington, 1874.

Ninth report of the U. S. Geological and Geographical Survey of the Territories, 1875. By F. V. Hayden. Washington, 1877.

Fur Bearing Animals. By E. Coues. Washington, 1877.

Ethnography and Philology of the Hidatsa Indians. By Wash. Mathews. Washington, 1877.

Contributions to North American Ethnology, Vol. 1. Washington, 1877.

Monographs of North American Rodentia. By Coues and Allen. Washington, 1877.

The Vertebrate of the cretaceous formations of the West. By E. D. Cope. Washington, 1877.

From the Hon. Secretary of the Interior, Washington.

Report of the Commissioner of Agriculture, for 1876. From the Commissioner.

Specifications and Drawings of Patents, for May and June, 1877. From the U. S. Patent Office.

Statistics of Mines and Mining in the States and Territories west of the Rocky Mountains, being the eighth annual report of R. W. Raymond. Washington, 1877. From the Author.

Practical treatise on Water Supply Engineering. By J. T. Fanning. New York, 1877. From D. Van Nostrand, N. Y.

Annual report of the Chief Engineer of the Water Department of Philadelphia, for 1876. From W. H. M'Fadden, Chief Engineer.

Small's Legislative Handbook. Harrisburg, 1877. From H. O'Neill.

Methods, discussions and results, meteorological researches for the use of the Coast Pilot. Part 1. Washington, 1877. From the Sup't U. S. Coast Survey.

Brief treatise on U. S. Patents, for inventors and patentees. By H. & C. Howson. Philadelphia, 1877. From the Authors.

Mr. William Welsh, chairman of the Committee on Primary Industrial Education, made a verbal report of progress, and presented the following resolutions:

1. "*Resolved*, That the Franklin Institute respectfully urges the Board of Education, and the Select and Common Councils of this city, to provide a thoroughly competent Superintendent of Drawing, who will not only instruct teachers in that practically important department, but will also assist in its introduction into all the Public Schools of this great manufacturing city."

2. "*Resolved*, That the Committee on Primary Industrial Education be authorized to add to its number from members of the Institute."

3. "*Resolved*, That Mr. John D. Runkle, President of the Massachusetts School of Technology, be invited to address the members of this Institute, on Primary Industrial Education, at such time as will suit his convenience; and that an invitation to attend the lecture be extended to the Board of Education, and the Directors and Officers of Girard College and the Pennsylvania Institution for the Deaf and Dumb, and the Directors of the Pennsylvania Museum of Industrial Art."

4. "*Resolved*, That the Franklin Institute, without committing itself to the details of the plan submitted by Prof. Ennis, gives its cordial approval of increased instruction in Natural Philosophy in our public schools, as a proper basis for industrial education."

On motion, the first and second resolutions were adopted; the third was referred to the Standing Committee on Instruction; and the fourth was recommitted to the Committee.

Mr. Hector Orr read the paper announced for the evening, on the Culture and Manufacture of Flax, Hemp, Jute and Ramé.

Mr. Samuel James gave an illustrated description of Seyss's Automatic Weighing and Sorting Machine for coins, now in use at the Philadelphia Mint.

The Secretary exhibited the apparatus, and described the methods employed to measure the power and light, and Prof. E. J. Houston, that for the electrical measurement, in the tests of dynamo-electric machines now being made by the Institute.

A letter was read, from Frederick Ransome, Esq., London, Eng., acknowledging receipt of notice of election as an honorary member of the Institute.

Mr. J. E. Mitchell offered the following, to be acted on at the next meeting of the Institute:

"*Resolved*, That the By-Laws of the Institute be amended by striking out all of Sections 5 and 7 of Article II."

On motion, the meeting adjourned.

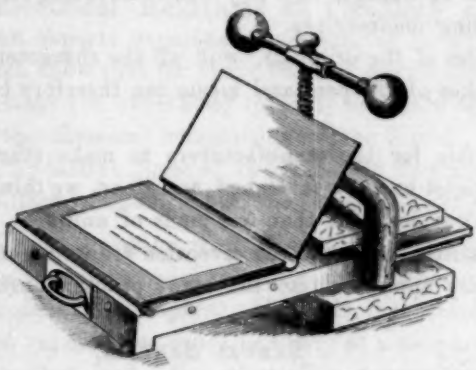
J. B. KNIGHT, *Secretary*.

ZUCCATO'S PAPYROGRAPH.

Report of the Committee on Science and the Arts of the Franklin Institute. Adopted August 1st, 1877.

The Papyrograph is a new process for the rapid production of fac-simile copies of manuscripts, pen drawings, &c. It was invented by Eugenio De Zuccato, of Padua, Italy, and patented in the United States November 24th, 1874, and January 4th, 1876. * * * * The process is very simple, and may be briefly described as follows:

The Company holding the patent, supply, to their licensees, sheets of paper that have been made waterproof by a resinous, flexible varnish, applied on one side of the paper; on the opposite side, the manuscript or drawing is to be executed with a steel pen, using a special ink composed of a concentrated alkaline solution with suitable coloring matter added to it. The effect of this ink wherever it touches the paper is to destroy its waterproof quality by attacking the varnish. The sheet is then floated on the surface of water, the written side uppermost, and in a few minutes the water makes its way up through the paper to the alkaline ink, and completes the solution of the varnish at those points. It is then brushed with a camel's hair brush and plenty of water, and all the dissolved varnish washed out of the pores of the paper, thus producing a porous stencil of the manuscript. A special printing ink or "color" is furnished, composed of glycerine and aniline violet; a small quantity of this color is brushed over the written side of the stencil sheet and it is then placed face downwards on a printing pad of velvet, which has been previously saturated with the same "printing color."



A waterproof folio is furnished, having a central leaf made of heavy sheet zinc, with an aperture slightly larger than the printing pad; the pad with the porous stencil being properly placed in the

folio, the zinc is turned down so that the marginal frame holds the stencil sheet in place on the pad, and then all is ready for printing. All that is now necessary is to place a sheet of ordinary paper on the stencil, close the folio on it, slide the whole into an ordinary copying press and apply a slight pressure for a moment; a portion of the color is forced through the stencil to the clean sheet in contact with it, and the copy is complete.

Several hundred copies may be printed from the one stencil, and without replenishing the printing color in the pad beneath it.

It will be seen by the foregoing description, that all the manipulations are simple and easily acquired, the materials and apparatus always ready and in order for immediate use. In the opinion of this committee, these are great advantages over any other method which they know of for duplicating manuscripts.

The copies are fac-similes of the originals, with all the characteristic light and heavy touches of the pen, and music can therefore be well duplicated.

We suppose it is possible for the manufacturers to make other colored inks besides the violet one now furnished, and if so, we think that a more permanent ink is desirable than one made of aniline.

In conclusion, the committee commend the invention for its ingenuity, simplicity, and its easy application to the many practical uses for which it is adopted.

(Signed), SAMUEL SARTAIN,
OTTO SUTHY,
HENRY R. HEYL,
Sub-Committee.

Lontin Magneto-Electric Machines.—Among the many candidates for favor in electric lighting, plating, etc., are the dynamo-electric and magneto-electric machines of Lontin & Co., 24 Rue Cassette, Paris. They are made both for continuous and for reciprocating currents, and the same machine may be used either as a motor or for lighting, or simultaneously for both objects. The regulation of the light is said to be so perfect, that it is specially adapted for naval service; pitching, rolling, wind, and the other inconveniences of navigation, have no influence on the steadiness of the light.—*Les Mondes.* C.

Writing Machine for the Blind.—M. Recordon, of Geneva, has invented a machine which enables the blind to write, both in characters which can be read by their blind companions, and in ordinary letters. He proposes to publish a journal for the blind, of which the first number will be issued at Geneva, Jan. 1, 1878.—*Les Mondes.* C.

Electric Conductivity of Trees.—Th. du Moncel reports a series of careful experiments upon the conductibility of trees. He finds a resistance, when the leaves are the points of contact, equivalent to from 200,000 to 400,000 kilometres of telegraph wire. In moderately large trees, at a height of 7 or 8 metres on the trunk, it is about 3000 kilometres.—*Comptes Rendus.* C.

Electrical Relations of Capillary Constants.—M. Lippmann reports experiments, conducted in the laboratory of Jamin, which show that for every value of electro-motive force, the capillary constant (or superficial tension) has only one value, whatever may be the chemical composition of the liquid. In other words, if the electro-motive force of two different combinations is the same, the capillary constant is also the same.—*Comptes Rendus.* C.

Vapor Density and Elasticity.—Alexander Morton publishes some ingenious and interesting experiments on the maximum elasticity and density of vapors. He finds that absolute alcohol and chloroform vapors have equal elasticity at a temperature a little above that of melted lead; that there is a temperature at which steam and bisulphide of carbon have equal elasticities; that cloroform may be vaporized and re-liquefied at a still higher temperature.—*Proc. Phil. Soc., Glasgow*, v. x. C.

Meteoric Rupture.—Showers of meteoric stones have been attributed, by Haidinger and others, to the joint attraction of separate bodies, forming a cluster which enters the atmosphere as a single mass. Maskelyne supposed that the detonations in the upper air, were due to the expansion of the outer portions, while the interior retained the extreme cold of the celestial spaces. Benzenberg sought an explanation in electric discharges, produced by violent friction. Daubrée has experimented with dynamite and steel, to show that "the fragmentary form of meteoric irons may be attributed to a rupture under the action of strongly compressed gases."—*Comptes Rendus.* C.

Diamagnetism of Hydrogen.—R. Blondlot finds that condensed hydrogen has diamagnetic properties of considerable energy, and that the diamagnetism increases in a greater ratio than the condensation. His experiments confirm some of the conclusions which Tyndall published in his researches upon crystalline bodies.—*Comptes Rendus.* C.

Nitrogen of Plants.—Berthelot has experimented upon the absorption of nitrogen by organic compounds, under the action of feeble electric currents, analogous to those which pervade the soil. He finds that he can thus account for the "unknown source" of vegetable nitrogen, which Lawes and Gilbert observed in their agricultural experiments at Rothamsted.—*Comptes Rendus.* C.

Forms of Molecules.—Prof. J. Clerk Maxwell, reasoning from the conclusions of Boltzmann's paper "on the nature of gas-molecules," concludes that the molecules of chlorine, ammonia and sulphureted hydrogen, are rigid elastic bodies; those of hydrogen, oxygen, nitrogen, air, carbonic oxide, nitrous oxide and hydrochloric acid, are smooth figures of revolution; and those of mercury-gas are smooth spheres.—*Nature.* C.

Venetian Sewerage.—The square of St. Mark, in Venice, is often flooded by the spring tides. Engineer Domenico Asti proposes to remove the inconvenience by conduits which will hold the greatest quantity of rain that ever falls in six hours, with self-acting gates, which open at low tide and exclude the waters of the lagoon at high tides. By an expenditure of $20,000, he thinks that all inundations could be prevented, except in the few very exceptional cases which occur only at intervals of many years. His paper is accompanied by drawings and detailed calculations.—*Il Politecnico.* C.

Electric Lighting.—The experiments with the Gramme machines are now daily repeated at the Palais de l'Industrie, in Paris. An area of 12,000 square metres is lighted by two electric lustres, of six lamps each, suspended at 27 metres from the ground. The power is supplied by two steam engines of 25 horse-power each. It would take 10,000 candles to yield an equivalent light on the floor, or 300,000 to illuminate the whole space as thoroughly. The subdivision of the light has been very successful. At first there was but a single lustre, then there were two, and it is proposed soon to introduce three.—*Les Mondes.* C.

Rail-Profiles.—Moritz Pollitzer, chief engineer of the Austrian "Staats Eisenbahn-Gesellshaft," has investigated the sections of steel rails, with a view to determine the profile which will give the greatest wear at the least cost.—*Zeit. des Oester. Ing.- und Arch.-Verein.*

C.

Manganese Bronze.—According to Gintl, a tough, malleable bronze, of nearly the color of brass, contained 76·710 parts copper; 16·147 manganese; 5·490 zinc; ·320 iron; ·762 tin and silicon. This represents an alloy of 15 parts copper, 4 parts manganese, and 1 part zinc.—*Techn. Blätter; Dingler's P. Jour.* C.

Spectrum-Projection.—By means of a Leyden jar and induction coil, and three Bunsen cells of 2 gallons, clear and continuous spectra can be projected on the screen, without a calcium light. The spectral lines are zigzag, like the sparks from the coil. Soda, copper, zinc, calcium, and brass, may be satisfactorily employed.—*Les Mondes.*

C.

Sketching-Paper.—MM. Carl Schleicher and Schüll, of Düren, Germany, prepare rolls of sketching-paper of excellent quality, and uniformly ruled in squares of 1 centimetre, ½ centimetre, and 1 millimetre on the side. The difference in the breadth of the rulings is so plainly marked that any projections can be readily made, without instrumental measurements.—*Pap.-Zeitung.* C.

Microscopic Organisms.—In two important papers, presented to the French Academy on April 30 and July 16, MM. Pasteur and Joubert show that the terrible animal disease which is known as *charbon* or *sang de rate* (carbuncular gangrene), is caused by microscopic bacteridia, which were first observed by Dr. Davaine, in 1850. It may, therefore, be classed with trichinosis and the itch, as a parasitic disorder. Vibrios, bacteria and bacteridia, are all found under two essentially distinct forms; either in translucent threads of variable length, multiplying rapidly by division, or in groups of little brilliant corpuscles formed in the interior of the threads, which separate from the parent, and constitute an apparently inert mass of points, from which countless legions of filiform individuals may come, having the same two-fold methods of reproduction. The threads may be killed by drying, or by a heat much below that of boiling water. The germs, when dry, withstand temperatures from 120° to 130° C., or 248° to 266° F.—*Comptes Rendus.* C.

African Scientific and Hospital Station.—The International African Association has established a depot at Zanzibar, and an agency in the Uniamwesi, which will enable it to place its first scientific and hospital station on the borders of Lake Tanganyika, or still farther in the interior.—*Comptes Rendus.* C.

Detection of Butter-Adulteration.—To determine whether butter has been mixed with inorganic or animal fats, P. Jaillard places a thin film between two strips of glass and examines it microscopically. If the butter is pure, only fatty globules can be seen; if it is adulterated, there will also be crystalline ramifications in greater or less quantity.—*Les Mondes.* C.

Confirmation of Franklin's Electrical Theory.—Edlaud has investigated the electrical currents produced by the flow of liquids in tubes. He finds that the existence of the currents cannot be explained satisfactorily by Du Fay's hypothesis, but that it can easily be accounted for by the theory of excess or deficiency in a single fluid.—*Pogg. Ann.*, clvi. C.

Domestic Use of Aluminum.—Recent experiments show that pure aluminum could be employed much more extensively than has generally been supposed, provided a cheap method was devised for procuring it. Spoons made from aluminum, from German silver, and from silver, were subjected for a year to constant use, under similar conditions. The resulting wear was 0·630 per cent. for aluminum; 1·006 per cent. for German silver; 0·403 per cent. for silver.—*Berg- u. Huetten-Zeit.* C.

Mousseron Brazier.—Abbé Moigno gives a detailed and interesting description of a brazier, invented by M. Mousseron (20, Boulevard des Filles-du-Calvaire, Paris), which may be used in close apartments without vitiating the air. Through the centre of the fire box, passes a tube pierced with holes, which admits a copious supply of air to the fuel, producing a vivid combustion, so that there is no production of carbonic oxide. The carbonic acid is absorbed by the vapor of water from a vessel near the top of the brazier, and escapes into the room in a harmless form. Numerous extracts are given from a report of M. Triboulet to the *Societé Nationale des Architectes de France*, and the invention is pronounced "the easiest, the most universally applicable, the most economical and the most agreeable of all the known methods of warming."—*Les Mondes.* C.

Indicator for Hot Journals.—M. Coret has contrived a simple apparatus for giving an alarm, when boxes are not sufficiently greased. It embraces a certain number of metallic tubes with elastic bottoms, filled with an expansible liquid, the whole enclosed in a small metallic cylinder. The instrument can be attached to a turning arbor, and if the arbor heats, the liquid dilates, forming an electric contact, which sounds an alarm.—*Soc. d'Encour. pour l'Ind. Nat.* C.

Abridged Labor.—In a paper on the division of the circumference into equal parts, Ed. Lucas introduces a process for accomplishing a calculation in thirty hours, which would have required three thousand years of constant labor under the old methods. It would take more than two hundred million centuries, at the rate of ten figures per second, to simply write out the numerical value of a quantity for which the expression can be written, in his formula, in less than half a second.—*Comptes Rendus.* C.

Wages-Insurance.—The Industrial Society of Reims recommends an addition to policies of insurance against fire, of a clause, providing for the payment of wages to the workmen, during the time that they are thrown out of employment by the necessary repairs. The proposal receives a qualified approval from a committee of the Industrial Society of Mulhouse, with a recommendation that the Alsatian custom, of reserving a fund in each establishment for such contingencies, should be more generally adopted.—*Bull. de la Soc. Ind. de M.* C.

Uses of Injectors.—The *Journal des Fabricants de Sucre* describes various economical applications of the Körting injector, in the removal of gases, liquids and solids. In chimneys that are sufficient for a given number of boilers, the addition of another boiler often weakens the draft, which may be restored by an injector. In one instance, two boilers were required, using in 230 hours, 78,120 kilogrammes of coal; after adding a Körting injector, only 36,375 kilogrammes were consumed in the same time for the same work, and only one boiler was required. The same injector has also been used as a smoke consumer; as a blower for stoves; as an extractor of carbonic acid gas; as a pump for well water, for thick and muddy liquids, for beet-juice, for milk of lime, for acids, for lyes and for locomotives at watering stations; as an elevator for animal-black, for grain and for granular solids; and as a sugar clarifier. C.

Anemometer Vane.—H. Wild has improved the anemometers of Pickering and others, so as to secure greater simplicity of construction, together with a more accurate measurement of the wind-force. Under deviations of 30° C. in the thermometer, and 80 millimetres in the barometer, the error of registered velocity would not exceed 5 per cent.—*Les Mondes.* C.

Self-Winding Clock.—F. Helling describes an automatic clock, in which the winding machinery is operated by the alternate expansion and contraction of glycerin, or other suitable liquid. A piston, on the surface of the glycerin, is so connected with ratchet wheels and toothed racks, that motion in either direction will wind up the weight. The inventor thinks that the contrivance will be especially valuable for self-registering meteorological instruments.—*Zeit. des Ver. Deutsch. Ing.* C.

Hydraulic Cement.—An excellent cement for foot-walks, and for all uses which require exposure to the weather or to dampness, is described in *Der Practische Maschinen-Constructeur.* It is made by thoroughly stirring Portland cement, or good hydraulic lime, into a warm solution of glue, so as to make a thick paste, and applying it immediately. In three days it acquires extraordinary hardness and tenacity. It is an excellent cement for joining the porcelain heads to the metal spikes which are used as ornamental nails. C.

Cosmical Meteorology.—At the meeting of the French Academy, on July 30th, M. Faye called attention to the supposed importance of looking for cosmical influences, wherever any cyclical meteorological disturbance is discovered. If the Greek astronomers had known of the daily tides, he thinks they would have known the earth's true place in the system, and discovered the law of gravitation. But he claims that the alleged cosmic influences are mysterious; that they have never taught us anything about the nature of the phenomena, and that we have reason to doubt whether the cosmic action is real. He proposes, as a criterion, that a simple resemblance of period is not enough, unless there is an *a priori* reason for conceiving the possibility of some bond between the phenomena. Applying this criterion, he disparages the labors of Wolf, Schwabe, Carrington, Lamont, Broun and others, who have sought to trace connections among sun-spots, magnetic variations, storms, and planetary influences. C.

Fire-Damp Explosions.—The *Annales des Mines* (T. xi, liv. 2) gives three papers on the relations of atmospheric pressure and coal dust, to explosions of fire-damp, and on the best means of preventing them. The French Academy has appointed MM. Daubrée, P. Thenard, and Berthelot, a committee to act with a committee of engineers, in studying remedial measures. C.

Crystallized Glass.—M. Videau, director of the Blanzy glass works, has obtained some fine specimens of crystallized glass, from a crucible that had been running for eight months and a half, in a Siemens furnace. He hopes to obtain still better crystals, together with the "mother-waters," from a furnace that seems likely to act for nine or ten months.—*Comptes Rendus.* C.

Discovery of Springs.—M. Baour states that in many cases, permanent supplies of subterranean water may be found by observing the quivering of the air on a clear summer day, when the sun is near the horizon and the air is still. By the aid of an assistant with two beacons, the outlines of the quivering area may be marked out, and wells dug at convenient points. The success of "divining-rod" wielders may, perhaps, have often arisen from a knowledge of this method.—*Les Mondes.* C.

Meteors.—In his closing communications to the French Academy, M. Daubrée gives an interesting summary of the various meteoric phenomena and markings which have been satisfactorily explained by his experiments with dynamite. Popular theories had previously assumed that there should be some such explanation, but positive evidence was wanting. In like manner, Abbé Nollet had pointed out resemblances between lightning and electricity, but the identity was not demonstrated until Franklin drew the lightning from the skies in 1752. C.

Influence of Trees on Moisture.—M. Fautrat has made observations in French forests, to determine the influence of trees on the distribution of rain and moisture. He finds that forests receive more rain than open plains, and pines more than leafy trees. Pines retain more than half of the water that is precipitated upon them, while leafy trees allow 58 per cent. to reach the ground. Pines, therefore, furnish the best shield against sudden inundations, and the best means for giving freshness and humidity to a climate like that of Algiers.—*Comptes Rendus.* C.

Improvement in Agricultural Analysis.—M. Ad. Cornot gives a new method of determining the proportion of potash in soils or mixtures. The analysis can be made in a few hours, the determination being as exact as if a much longer time had been employed. —*Comptes Rendus.* C.

Slipping of Locomotive Wheels.—M. Rubeuf finds that the slipping of locomotive wheels, on down grades, varies between 13 and 25 per cent. There is, consequently, a great loss of fuel, and a great wear of tires and rails, from this cause alone, which is deserving of special study.—*Comptes Rendus.* C.

Pasteur's Triumphs.—Bastian has withdrawn from the proposed test of his views by the French Academy, on account of dissatisfaction with the constitution of the committee. P. Bert has given his full adhesion to the interpretation which MM. Pasteur and Joubert gave to their experiments upon carbuncular gangrene. In a communication presented to the Academy on July 30th, he states that he has successfully repeated the experiments, which show that the virus is due to living bacteridians. C.

Orbit of a Bolide.—M. Grucy, by combining observations at Bordeaux, Augouleme and Clermont, has calculated the orbit of a bolide, which he found to be within 23° of its perihelion. Its velocity, relative to the earth, was 68 kilometres, or about 45 miles, per second. Its orbit, like some of those calculated by MM. Galle, Tissot and Heiss, was very hyperbolic; it must, therefore, have come into our system from the stellar spaces.—*Les Mondes.* C.

The Plethysmograph.—M. Mosso, of Turin, has invented an instrument for observing the variations in the circulation of blood in the arms, under the influence of natural or artificial causes. The entrance of a person into the room, causes a diminution of the forearm, which may vary between 4 and 15 cubic centimetres, the blood quitting the arm and mounting to the head. Thought and cerebral activity seem to be in proportion to the contraction of the vessels of the forearm. During sleep, dreams cause a depression in the circulation of the arm. Just before waking, there is a like depression. The experiments confirm the theory of Durham, Hammond and Ehrmann, that the brain receives less blood during sleep, than when awake.—*Les Mondes.* C.

Book Notices.

THE ELEMENTS OF DESCRIPTIVE GEOMETRY, SHADOWS AND PERSPECTIVE.—With a brief treatment of Trihedrals, Transversals and Spherical, Axonometric and Oblique Projections. By D. Edward Warren, C. E. 8vo, pp. 282, with detached plates. Jno. Wiley & Sons. New York, 1877.

Having carefully examined the above work, especially with reference to discovering its advantages over other similar works, we find that the ordinary classification of lines, surfaces and volumes is retained, but the order of demonstrations is somewhat modified by treating each class of objects under the four divisions: A, Projections; B, Tangencies; C, Intersections; D, Developments. The objects treated of in Orthographic Projections are divided into the two grand divisions of Surfaces of Revolution and Transposition. The latter class is defined to be that including all surfaces generated by a "line moving in any other way than by revolution about a fixed axis." As many surfaces, such as planes, single curved and some warped, may be formed by both methods, they are classed and treated under both divisions, leading to a separation of principles and problems otherwise closely related, as well as to a redundancy which strains the attention.

In the analysis of the individual problem, the author states first the theorem, then the description of the positions and motions *in space*, and lastly *in projection*. We do not think the discussion of the positions *in space*, gives so clear an idea nor does it develop so well the conceptions of methods, as a brief analysis stating concisely the principles to be employed. Neither have we found any new matter nor methods. The use of the word *trace* to designate the point in which a line pierces the planes of projection, introduces an ambiguity, as the same word also denotes the intersection of those planes by any third plane, thus confusing the student. The drawings in oblique projection, showing at once the objects in space as well as their projecting lines and projections, may be of service to the beginner, but these features may be much better illustrated by card-board models or a hinged blackboard with a perforated glass triangle for an oblique plane, and glass or wooden rods for lines. In short, we cannot see that the work is any improvement upon those of the same nature now in use, some of which cover almost the same ground in about one-half the number of pages.

H.

INDUSTRIAL DRAWING.—By Daniel F. Thompson. 8vo, pp. 209. New York, 1877. John Wiley & Sons. Price, $3.50.

This is a revised edition of a work by the late Prof. Mahan, which has been enlarged by the addition of chapters on Tinting, Shading, Shadows, Isometric and Oblique Projections, and Perspective. The classification is good and the language plain, but we are unable to find much new matter in the work. The information concerning instruments and their uses, having been so often repeated, seems superflous; the same may be said of many of the Geometrical problems; yet it is true that the book would be incomplete without them. The general principles of projections and their applications, have been so concisely and fully expounded by Church, Davies, Binn, Warren, Adhemar, and others, as to leave nothing to be desired in that direction, unless it be some new or extended application. The rules given on page 144 for *graduating* the shade on an oblique *plane*, are opposed to the theory of reflected rays from plane surfaces, and mislead the student by giving to one plane the appearance of two or more, intersecting at different angles. We notice, also, a slight error on page 192, concerning the datum surface for levels referred to the sea —It should be *mean low* tide instead of "the *lowest level of tide water*," and distances measured vertically *below* this surface are not generally distinguished from those above by the opposite algebraic signs + and —, but by the shore or water line. They are expressed in feet and fathoms, and are positive.

The hachure system of representing topographical features we have never considered of any practical use for indicating degrees of slope, as its value is entirely dependent upon the accuracy and skill of the draughtsman and engraver, of which the reader can know nothing, nor can he determine frequently whether any attempt has even been made to apply the rules for the shade of slopes. As it is, however, a recognized system, it must enter into such a work, but should only be used for relief maps and not for accurate slope representations. For this latter purpose, the *contour* system is infinitely better, and its applications of much practical value. The author does not even use the term *contour*, much less define it, but speaks of it as the horizontal curve (it may be a straight line). The codes of conventional signs and tints are also incomplete. There is one important division of Industrial Drawing which is not mentioned in this treatise, and that is its application to the Industrial Art, now attracting so much attention, and without which no work with this title can be considered complete.

With these exceptions, we believe the work will compare favorably with its compeers, and be found useful by all desiring to study the Art of "Industrial Drawing."

ON THE DIRECT PROCESS OF MAKING WROUGHT IRON AND STEEL.[1]

By Chas. M. Du Puy, C. E.

It is scarcely necessary, at this late day, and before this Institute, to explain the difference between the "direct" and the "indirect" methods of producing iron that can be forged. Suffice to say that by the primitive "direct" method, 400 or 500 lbs. of ore, mingled with charcoal, are subjected to the action of blast for 3 or 4 hours, when it becomes imperfectly matted together, and is transferred to the hammer; where its earthy impurities, being melted, are removed by pressure. This process secures a high grade of iron, at the cost of about 300 bushels of charcoal and great waste of ore to the ton of iron.

The "indirect" method treats large masses of ore, carbon and fluxes in the blast furnace. Deoxidization takes place early in the first stage, but afterwards under the action of a powerful blast the metal and metalloids are all mingled, and 3 to 5 per cent. of carbon is incorporated. The earthy impurities are then mainly separated by specific gravity and tapped off, still the pig iron may be said to be a compound of iron, carbon, silica and other substances which require a second melting, and laborious manipulation, to purify the metal for forging or rolling.

To improve and cheapen iron by the "direct" method, has occupied the attention, and baffled the efforts, of many earnest men for three-quarters of a century. The devices have been numerous. In 1791, Samuel Lucas patented a process for reducing ores with carbon in air-tight pots. In 1794, Mushet forged iron which he had carefully reduced, away from the atmosphere, and brought to the pasty state in a crucible. Others, later, passed over the same ground, for the superiority of the metal when reduced and welded, uncontaminated by the oxygen of the blast, or furnace gases, had been observed, and stimulated to further effort.

The reduction of ores in crude clay pots, it is likely, has been known to the people of Asia for a thousand years, if indeed it was not almost cotemporary with the earliest manufacture of iron, for it would seem to be one of the simplest ways of producing metal in small quantities

[1] A paper read at the meeting of the Franklin Institute, Oct. 17th, 1877.

and of superior quality. While ordinary Wootz was usually made first into iron in small blast furnaces with light pressure, and then melted again in small pots, it is not unlikely that the famous sword-blades of Damascus, and celebrated scimitars described by Alexander Burnes in his journey to Cabool—where one was shown him that was valued at 5000 rupees—were the product of ore first deoxidized and imperfectly welded or matted together in crudely made clay pots, and then, after being hammered, again melted into a more superior Wootz in other clay pots.

A fresh pot, however, for every operation, even of the rudest and cheapest manufacture, was of course too expensive for any very extended use, and a half century ago, devices began to be suggested in which the ore could be deoxidized in a close vessel, and then emptied into a balling hearth, and so the vessel be used over and over again. To that end, the files of our own patent office, and those of Europe, exhibit a variety of inventions and processes, dating up to the present time, but they may be all divided into three classes:

1. Close retorts or crucibles of various shapes and sizes, heated from the outside, being substantially the "*Air-tight Pots*," patented by Lucas.

2. Tables of refractory material, heated from above and below, on which the ore and carbon were placed and stirred, and finally transferred to a balling hearth.

3. Revolving cylinders, containing ore and carbon, and heated from the outside, or within.

In the first two classes, deoxidization was *supposed* to be completely accomplished in the first operation, and the balling was done in a second furnace, but in the *last* class, Dr. Siemens' invention, the rotary cylinder, the gas from the producers is poured into the *inside* of the cylinder, until not only complete deoxidization is effected, but until the metal in the pasty state may be divided into balls, for removal to the hammer.

Many years since, being convinced by a long series of experiments that iron reduced from ore in close pots, and out of reach of external oxidizing influences, was of superior quality, I tested many devices for placing this mode of manufacture on a practical working scale.

In the course of these experiments I found that ore and carbon are such perfect non-conductors, that the highest heat penetrates from the outside very slowly through a thickness of about 3 inches of this substance, and that to add 2 or 3 inches thickness of crucible or

containing vessel, practically defeats complete reduction in a sufficiently speedy time to be successful, and has been the main cause of the failure of this class of inventions.

Although the authorities generally give us the "*cherry red*" and the "*bright cherry red*" heats as the best condition for deoxidization of iron ores, yet I have found these heats wholly unfitted for complete reduction, in such periods of time and at such cost, as to make the manufacture commercially profitable. A thorough reduction of any considerable mass of iron ore, with heat penetrating from the *outside*, in the space of 5 or 6 hours, is so closely allied to a *white welding heat*, that it seems impossible to separate it; and to deoxidize ore only 2½ to 3 inches in thickness, within that time, I find most profitable to drive the furnace up gradually to a high welding heat, at which, finally, it is penetrated through and through, passing into the pasty state and settling down into a metallic mass, interspersed with liquid slag.

Now a crucible or pot of any refractory material, sufficient to withstand a heat from the outside that would bring the 2½ inches of ore to iron in the pasty state, in any considerable quantity for but a very few operations, would be costly at first, and costly in frequent renewals. Beside this, any material of which it might be composed, would soften at the pasty state of the iron, and become more or less incorporated with the metal in the difficult operation of withdrawing it, and so the iron would be seriously deteriorated.

To secure the advantages of the "*close pot*," it became evident that some substance should compose it, that should withstand the high welding heat, and be homogeneous with the metal, and, finally, when its work was done, and the ore changed to metal, would *weld up with it*.

In this dilemma, after testing various materials, I conceived the idea of using *thin sheet iron* as *an encasement, or canister*, having found by experiment that it would resist a high heat for several hours. These sheet iron vessels, filled with ore and carbon, during several years, were tried, of all sizes and shapes, and in almost every conceivable furnace. It was found that superior iron could be produced in these canisters in 7 or 8 hours, but the *yield* was *unsatisfactory*, when over 5 inches in thickness, owing to a failure of thorough reduction, and of that diameter, the cost for sheet iron was *too large in proportion* to the iron obtained.

Still believing that the process could be made practical, and the metal be produced in from 4 to 6 hours at a low cost, the canisters were placed on a coke bottom, in a reverberatory furnace, which was

driven with blast, to produce an outward pressure—although the coke kept the bottoms heated, which otherwise would have become chilled, yet it was found impossible to increase the size of the canisters, as the heat would not penetrate more than 5 inches thickness to reduce and consolidate the ore to metal, in a reasonably economical period of time.

Finally, the canisters were made *disk* shape, that is to say, a cylinder of 6 inches diameter was placed inside of one about 16 inches diameter, and a bottom being provided between them, the ore and carbon were filled within the annular space, leaving the space within the smaller cylinder open, thus making a ring of the ore mixture, so that when the canisters were placed on end, in the furnace, on the coke bottom, the heat could penetrate from the inside as well as the outer surfaces. By this arrangement these cylinders can be two or three feet high, and yet all the ore can be penetrated with heat traveling not more than $2\frac{1}{2}$ inches.

Although this improvement was found highly advantageous for rapid reduction, yet it was not fully satisfactory, owing to the oxidizing gases of the furnace, which still wasted metal by reoxidation; for I would remark here, that however perfect it is possible to make a *reducing heat*, in a reverberatory furnace, still the combustion necessary to produce a *high* heat, is more or less *oxidizing* to the ore in its sensitive transition condition to metal.

As it is estimated that every pound of silica ordinarily carries with it about three pounds of iron, it occurred to me, to create for the silica a greater affinity than it has for the metal, by mingling alkalies, and to so proportion them, that the glass thereby produced by not combining with it, should not only save the iron, but that it should be further utilized by forming particles of glazing or varnishing material, covering the little particles of metal as formed, and thus protect them from furnace reoxidization. This step proved effective. Now the alkalies in quantity, and kind, having been determined by an analysis of the ore, they are mingled with it along with the carbon, and are all pulverized together, by being thrown, in the proper proportion, into an ordinary *Chilian mill*, such as is used in Western rolling mills for grinding the "*fix*" and from thence shoveled at once into the canisters, and charged into the furnace.

The carbon for deoxidizing may be either charcoal, or coke from washed bituminous coal, or washed anthracite dust. The iron, with either kind of carbon, is thoroughly reduced, and under the hammer and

rolls, or in the steel pot, I have *yet observed* no difference in the product. This mode of working must ultimately afford a market for the mountains of anthracite coal dust now wasted in our coal regions.

There are four ways of working this process, according to the purpose for which the metal is desired:

1. If it is desired to make steel, the canisters, filled as described, are charged on end into the furnace on a layer of coke, a few inches in thickness, so as to allow the heat to penetrate from the bottom, as well as sides and top. They are usually placed 7 or 8 inches apart to secure a radiation of heat between them.

In the course of from five to seven hours, according to the strength of the heat, the ore will be reduced from its oxide and settle down into almost a solid metallic mass, so firm as to be separated and broken with great difficulty, even in its highly heated state in the furnace. In this solidified condition it is removed and hammered, or thrown into the squeezer and rolled to muck-bar, at this one first heat. It is then cut up, reheated and piled, with the usual loss of 8 to 10 per cent. of ordinary piled iron. This stock is then fitted for the steel pot, producing all grades of steel, up to the highest, without mixing with other stock, but by simply varying the carbon.

2. The caked metal may, if preferred, be taken in its heated state to the Siemens open hearth, or other highly heated furnace, and there quickly melted with or without the usual carbonizing bath of pig and spiegel. In the condition of white heat, in which it is charged into this last furnace, it is admirably adapted for a rapid conversion to steel in large quantities, and at great economy of fuel.

3. The metal, when reduced, I have melted down in the same furnace and carbonized with pig iron. In operating the entire process in one furnace, the product may be brought out as either iron or steel at pleasure, by varying the carbon introduced at or before the time of melting.

If iron is required, as soon as the metal has separated from its impurities, precipitated to the bottom and covered with slag, the operator at once rolls it up in balls and subjects it to the hammer or squeezer. No excessive labor is required in stirring the metal, as is required to *decarbonize pig iron*, for this metal has *been deoxidized* without labor, simply by the chemical action of heat on the material; and there is no *excess of carbon to eliminate.* It has also separated itself, in the liquid state, by specific gravity, from its metalloids altogether, without the aid of physical labor. Finally, as it lies at

the bottom of the furnace, it is incorporated with *just sufficient* carbon as is needed by the operator to produce the grade of metal required.

I will remark here, that the iron produced by this process, in cakes of metal, is generally *red short in its nature.* It does not matter with how much carbon the ore may have been mingled, still it refuses to receive more carbon than to produce deoxidization, until it is about to pass to the pasty state and is brought almost to a melting condition.

This "red short" tendency, as the following analysis proves, proceeds from the *purity* of the metal, and not from an alloy of sulphur or other deleterious substances.

Believing that the red short could be cured by alloying *red short* and *cold short*, or *phosphoreted ores together*, I found, by a number of working tests, the product *still red short.* I then tried ores charged with *phosphorus alone*, which, if worked alone in the old processes, would have given highly "*cold short*" metal, but still my product was "*red short.*"

I then incorporated cast iron roll turnings with the mixture, and found that the alloy of carbon with the metal, in the pasty state, and as it become melted, lessened in a very marked degree the red shortness under the hammer. After that I introduced pig iron at the melting stage, observing again the same marked improvement in the metal under the hammer. So that I have finally come to the conclusion, by practical tests, that when the metal is alloyed with sufficient carbon, the red shortness may be removed.

Dr. Siemens, in his late address before the Iron and Steel Association, in their meeting at New Castle, ascribes this "*red shortness*" to "*slag shortness,*" as he terms it, because, on repeated pilings and reheating, this tendency is gradually removed. My own experience is different. I have not been able to remove the "red short" by repeated heating and piling, but find I can only remove it by alloying the metal with carbon.

4. Another method I have adopted in working this metal, is to take the cakes as reduced, at their white heat, and *sink* them in the forge fire. The quality of the metal is thereby highly improved in toughness, as is illustrated by samples of sheet iron here exhibited. By throwing the heated metal into the forge fire in this way, they sink, and are taken to the hammer in a half hour, with half the expenditure, both of fuel and labor, that is ordinarily required in sinking scrap in the forge fire. Still, even in the forge fire, "*red*

shortness" is *not cured.* This is accounted for by the rapidity of passing the metal before the tuyere in the melted state, which does not give time for the absorption of carbon, and, although improved in every other respect, it comes from the forge fire *nearly as red short* as when it was thrown into it. It requires the longer contact with carbon than is there so briefly allowed.

"Red short," produced, as it is, by purity of the metal, and not from sulphur, is not prejudicial in melting for steel purposes, for in all cases the steel is of the finest quality, ranking with that made from the best *Swedish brands of iron*, as the samples here exhibited prove. For many uses of iron, too, a strong red short tendency is not only unobjectionable, but is required. Still, for neutral iron, the *red shortness* must be cured, and this can be done at pleasure with an alloy of carbon *in the melted state.*

The purity of iron made by the *direct* processes, has always been a subject of remark, in contrast with that which is made by the *indirect* methods. Even particles of iron, *taken from a mass* of slag highly charged with phosphorus, on being analyzed, have been found of extreme purity.

It will be observed, by the analysis of Dr. Wuth of the iron made by my process, that about three-quarters of the phosphorus have been eliminated from the Republic ore which was used, and which he analyzed. A correct solution as to how the phosphorus is eliminated by the direct processes, when it *clings so closely* to *pig iron* made from *phosphoretic ores*, and *cannot* be eradicated from the *Bessemer converter*, when phosphoretic pig is used, is now occupying the attention of the ablest metallurgists of this country and Europe.

The best theory I am able to suggest, is that as the phosphorus melts at a low heat, and the metalloids also melt, when combined with suitable fluxes, at a much lower heat than the metal, that the phosphorus becomes incorporated with the glassy slag of the metalloids, and never afterwards leaves it, and that finally, when the metal is pushed to the melting condition, in the quiet heat of "the open hearth" furnace, the phosphorus floats with the slag, and cannot contaminate the metal in this *quiet* heat, as it does under the intensely violent *mixing* action of the blast in the Bessemer "converter," or in the blast furnace.

It will be observed that a triple chemical operation begins to take place at once, from the moment the canisters are charged into the furnace.

First. The oxygen of the ore combines with the carbon, passing off as carbonic oxide.

Second. The silica and alumina combine with alkalies introduced, and form the glazing material which cover the particles of newly-made metal, effectually sealing these particles from reoxidation from the furnace gases.

Third. The phosphorus melts into this glass, and passes off with it as a slag, *not contaminating the iron.*

The average of 14 analyses of *the ore* from the Republic Mine of the Lake Superior district, gives:

Metallic iron,	68·48
Phosphorus,	·053
Silica,	2·07

The analysis of reheated iron from the same ore made by my process, as given by Dr. Otto Wuth, of Pittsburg, is as follows:

Carbon,	0·042
Silicon,	0·021
Sulphur,	0·032
Phosphorus,	0·016
Slag,	0·185
Iron,	99·700

A comparison of the foregoing analysis with the analysis of some of the well known and most superior Swedish and Russian brands, is herewith given, showing a very marked resemblance:

	Dupuy.	From Dannemora Magnetic Ore.				From Russian.	
		L	Sykes. O O	J B	K	CC ND	K3 KB
Carbon,	0·042	0·087	0·054	0·087	0·386	0·272	0·340
Silicon,	0·021	0·115	0·028	0·056	0·252	0·062	trace.
Sulphur,	0·032	0·220	0·055	0·632	0·757	0·234	00·66
Phosphorus,	0·016	0·034	trace.	0·005	trace.	.....	.....
Manganese,	.....	.....	trace.	.....	trace.	0·020	trace.
Arsenic,	.....	trace.	.....	trace.	.....	trace.	.....
Slag,	0·185	.....	.....	.....	.....	.....	.....
Iron,	99·700	99·544	99·863	99·220	98·605	99·412	99·594

I come now to a consideration of the successful working of this process on a profitable commercial scale.

The ore, carbon, and fluxes, as has been proved by working, may all be ground together and charged into the canisters at an outside cost of 40 cents per ton of ore; when systematized, 30 cents per ton will be sufficient.

Canisters of No. 26 sheet iron, 15 inches outside diameter, and 13 inches high, with a tube 6 inches diameter passing through and through in the centre, including top and bottom, will weigh 6 lbs. They will hold 116 lbs. each of 67 per cent. ore, beside the carbon and fluxes. This has been the size that has generally been used, and each canister will yield from 75 to 80 per cent. of the metallic iron, including the 6 lbs. of sheet iron canister.

It is believed that in a furnace adapted to the purpose, the canisters may be made 16 inches diameter and 38 inches high, or even larger, and placed 6 or 8 inches apart all over the floor of a large reverberatory furnace.

Suppose a furnace is constructed 10 by 15 ft. inside capacity, to hold 5 rows of these canisters one way, with 7 canisters in the other, placed 8 inches apart and 8 inches from the furnace walls, then the furnace would hold 35 canisters, each containing about 400 lbs. of ore. They would be reduced in 6 to 7 hours, but say 3 charges of the furnace were made in 24 hours. Each canister of 400 lbs. of ore, yielding 80 per cent., or 230 pounds of the metallic iron hammered or squeezed, would give 8000 lbs. of iron at a charge, or 24,000 lbs. of muck-bar every 24 hours. I have found either natural draft or blast may be used.

The cost for canisters—11 to the ton of iron, say 15 lbs. each, would be about 180 lbs. of common sheet iron to the ton of product, which would include all kinds of defective sheets made at a mill, and also include the making of canisters—which is very simple, as may be seen by the sample exhibited—not exceeding in all, $5 to $6 per ton for the iron produced, and probably still less. This cost of canister per ton equals about the cost of breaking pig and puddling it in the old method, with the additional advantage that the work is reduced to extreme simplicity by the use of unskilled labor, and is in strong contrast with the excessive and laborious manipulation in decarbonizing pig iron in the difficult operation of puddling.

This process is very economical in welding together scrap. Ordinary scrap iron may have been so often worked over, at high heats, as to be exhausted of its cinder, such as the scrap from wrought iron

pipe, or it may be the thin waste ends from sheet iron, or of any other quality of iron subject to excessive waste in the ordinary working. I charge it all, whatever it may be, with the ore and carbon in the canisters, and it is *then protected* from oxidizing, being thoroughly enveloped with the carbon, until the whole mass of scrap and ore is consolidated and taken to the hammer. Ordinarily, light scrap is very largely wasted by oxidation in the reverberatory *scrap furnace* and *forge fire*, ranging in loss all the way up from 15 to 20 per cent. By this process I get very nearly the entire weight back.

Having given the cost of grinding the mixture, of canisters, and filling them, and shown by the samples that reduction may be effected by anthracite coal-dust, or other cheap and wasted fuel, it remains to state that the cost for heating the reverberatory furnace will be about $2 per ton of iron, as near as can be approximated at the present prices of fuel; and that the labor in charging and discharging from the furnace and rolling to muck, will not exceed $3 to $4 per ton, including cost of running machinery.

The following is an estimate for canisters of reduced metal, transferred white-hot to the "Open Hearth Furnace" sufficient for 1 ton of steel stock:

1¾ tons rich ore, at $3.50, or . . . } 2¾ tons impure ore to be separated, at $2.25, }	$6 13
Anthracite coal dust, for deoxidizing, ½ ton, at $1.50,	0 75
Crushing ore, coal and fluxes, mixing and filling canisters by automatic machinery, . .	1 00
Gas for reducing, ...	2 00
Canisters, 180 lbs. sheet iron, including making, at 3¼ cents per lb., ...	5 85
Labor to the ton, ...	1 00
Fluxes, ...	0 50
For one ton of steel stock transferred to the open hearth, ...	$17 23
For muck-bar, add cost of hammering or squeezing and rolling, say	1 00
	$18 23

To both estimates must be added, the usual items for wear and tear and general expenses.

Summing up all the data given, it will be found that muck-bar may be produced for $8 to $10 per ton above the cost of pig iron; that it will rank with the highest grades of wrought iron for special pur-

STATEMENT OF IRON MADE DIRECT FROM THE ORE, BY DU PUY'S DIRECT PROCESS, MANUFACTURED AT PITTSBURG AND VICINITY.

Date of Charge, 1877.	Kind of Ore used.	Kind of Furnace used.	At what Mill manufactured.	Number of Canisters in charge.	Outside diameter of each, in inches.	Inside diameter of each, in inches.	Height of each, in inches.	Weight of each Canister, in pounds.	Weight of Ore and Canister contained in the charge, in pounds.	Weight of Metallic Iron composing the Ore & Canister in the Charge.	Weight of Bloom from charge.	Weight of Muck-bar from the charge.	Per Cent. of yield from the metal contained.	Kind of Carbon Used.	Gas draft or Blast.	REMARKS.
Jan. 25.	"Republic."	Siemens' Heating.	Union Iron Mills, Pittsburg.	3	15½	6½	14	9	375	260		218	84	Charcoal.	Gas.	Reduced in 6 hrs.
" 29.	"	"	" "	2	15¼	6½	15½	9	270	187		160	86	"	"	" " 7 "
" 29.	"	"	" "	2	15¼	6½	15½	9	270	187		145	77	"	"	" " 7 "
Mar. 21.	"	"	" "	12	14	7	13½	7½	966	676		530	78	"	"	" " 5½ "
April 6.	"	Ordinary Heating.	Anderson Steel Works Pittsburg.	3	14	7	14	7	261	181	140		77	"	Blast.	" " 6 "
" 6.	"	"	" "	3	14	7	14	7	261	181	130		72	"	"	" " 6 "
" 10.	"	"	" "	3	14	7	14	7	291	201	161		80	Anthracite.	"	" " 6½ "
" 10.	"	"	" "	3	14	7	14	7	286	198	161		81	Coke.	"	" " 6½ "
July 18.	"Chateaugay."	"	Crescent Steel Works.	1	15	6½	14	6⅜	91	63	48		77	Charcoal.	"	" " 7½ "
Oct. 9.	"Iron Mount."	Puddling.	W. D. Wood & Co., McKeesport.	3	15	6½	13	6	333	229	163		71	Coke.	"	" " 10 "
" 9.	Penn. "Pipe" or Limonite.	"	" "	3	15	6½	13	6	282	181	156		86	"	"	" " 8 "
" 11.	"Iron Mount."	"	" "	3	15	6½	13	6	337	231	169		73	"	"	Transferred hot to forge-fire, then hammered & weighed. Reduced in 10 hours.

NOTE.—The Mitaic Iron in the Republic, Chateaugay and Iron Mountain Ores is averaged at 67 per cent., and 62 per cent. for the Limonite or Pipe, which last was roasted. The time required for reducing, varied with the intensity of the heat. It is believed 5 hours will be found sufficient, with the experience obtained by continuous working.

poses; and that the plant is so simple and inexpensive, as to make a large *reduction* in the interest account of all iron works. Besides this, it will be found that the process is so greatly under the control of the operator, as to enable him to make such mixtures as to produce the *exact quality* of iron or steel desired, not being subject to the irregularity of the blast furnace, which often, as is well known, for days together, gives a run of undesirable metal, baffling the utmost skill of the manager to change it. This direct process, in a word, reduces the exact results of the laboratory to a large and intelligent practical working basis for the manufacture of iron and steel; and, as such, I respectfully submit it to the impartial and unprejudicial consideration of the members of this Institute.

Relative Cost of Water and Steam Powers.—The cost of the water power equipment at Lowell, was, for canals and dams, $100, and for wheels, etc., another $100, per horse power. But this, as a first experiment, was more costly than a similar equipment need be. At Saco, the expense incurred was $175 per horse power; but at a later period, for turbines with high heads, the expense would be less. A construction and equipment, solidly carried out, with the latest improvement in wheels, would not cost over $200 per horse power, and would, under favorable circumstances, cost less. An estimate at Penobscot, was for $112.50 per horse power. If the construction be with wooden dams, and the equipment with lower grade wheels, then the cost would be about $50 per horse power; and although the construction would be less permanent than the more solid, it would outlast any steam apparatus. On the other hand, Fall River estimates of steam equipment, exclusive of foundations and engine houses, run from $100 to $115 per horse power. A Boston authority gives $115 per horse power for nominal 300 horse power and upward, inclusive of foundations and masonry. Similarly, a Portland authority places it at $100 per horse power. The actual cost of steam equipment in the water works of various cities of the United States, varies from $150 to $300 per horse power.

As to the cost of work done, it appears that in Philadelphia, in 1867, the cost of raising water by water power, was only 2 cents per 1,000,000 gallon feet; whereas the cost by steam power was in four cities $8\frac{3}{10}$, $11\frac{1}{10}$, $19\frac{1}{10}$ and $29\frac{2}{10}$ cents, with coal at $5.50 per ton.—*The Water Power, Maine.*

ON A NEW TYPE OF STEAM ENGINE, THEORETICALLY CAPABLE OF UTILIZING THE FULL MECHANICAL EQUIVALENT OF HEAT-ENERGY, AND ON SOME POINTS IN THEORY INDICATING ITS PRACTICABILITY.

Presented at the Nashville meeting of the American Association for the Advancement of Science, 1877.

By Prof. ROBERT H. THURSTON, Vice-President.

(Continued from Vol. lxxiv, p. 325.)

XXI.—Were it possible to conduct this operation of re-working the rejected heat by passing it through the first cylinder again, instead of being compelled to use additional engines, it would be decidedly more satisfactory than the use of the Binary class of engines. We may naturally next consider the possibility of returning to the reservoir all heat rejected in engines using vapors, as of water, as their working fluids. As the regenerator system is inapplicable here, it is necessary to secure the return of that unutilized heat by restoring to the reservoir all exhausted gas or liquid, or both, without seeking to remove from them and to restore separately the heat with which they are charged. Fortunately, the conditions which make the use of the regenerator system impracticable, are favorable to the adoption of the expedient which has been described as characterizing the operation of engines of Type B.

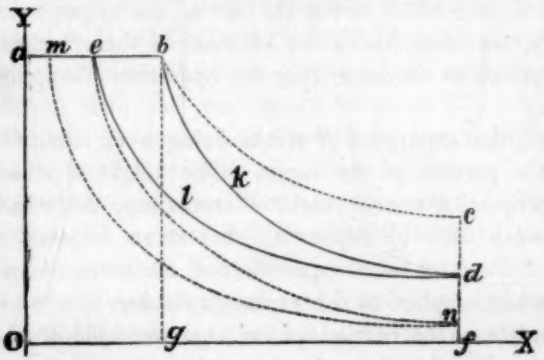
As has been seen, the expansion of steam doing work results in the condensation of a portion of the vapor. The weight of steam condensed bears a proportion to the weight of steam supplied, which is greater as the work done by expanding that steam becomes a greater proportion of the mechanical equivalent of the thermal contents of the steam when supplied to the working cylinder.

Suppose the expansion to be carried so far that one-half of the vapor becomes liquid. Imagine the water of condensation separated from the uncondensed vapor, and the two masses returned to the boiler separately by compressing pumps. The return of the water would involve the expenditure of an amount of work measured by the product of the volume of that water into the difference of pressures in the boiler and in the receiver into which the exhaust has been discharged. The return of the uncondensed steam would involve

not only the return of the charge of heat contained in that steam, but also the return of all the energy which the vapor had yielded during its expansion; since an equivalent amount of heat would be generated by its recompression to boiler pressure.

Under the conditions now assumed, it is evident that only that portion of the heat entering the engine which is surrendered by the condensation of steam doing work can be utilized. It is also evident that, in this form of engine, no heat can be lost; and, consequently, that the engine of Type B, which is operated as just indicated, will have yielded the exact equivalent of the net amount of heat expended upon it. All heat rejected from the working cylinder, unutilized, being returned to the boiler, there to form "a basis on which to pile up a new stock of utilizable energy," the engine is a "perfect engine" in a broader sense than that adopted by Carnot. It is further evident, that perfect efficiency is given for all ranges of temperature, and that what working fluid shall be adopted and what temperatures shall be chosen, will be determined simply by practical conditions to be ascertained by experiment.

The work done in restoring the water of condensation to the boiler being so small in amount that it may be neglected, the ratio of the total work done in restoring rejected heat to the work done by the steam on the piston will be the ratio of the weight of steam restored to the boiler of the engine to that supplied to the working cylinder at each stroke. Altering an engine of the common type, having an efficiency of 0·25, into an engine of Type B, the quantities of work done during expansion and during compression will have the ratio, nearly, of $1 : (1 - 0{\cdot}25) = 0{\cdot}75$.



The indicator diagram of our new engine will be similar to that shown in the accompanying figure, in which the ordinates of the curve measure the pressures, and the abscissæ are proportional to

the volumes of the expanding fluid. The steam expands from the volume $g\ O$ to the volume $f\ O$, when doing work, and from the pressure $O\ a$ or $b\ g$ to the pressure $c\ f$, when expanding according to Boyle's law. Doing work, however, the gradual condensation of the fluid reduces the pressure during expansion, and the line becomes $b\ k\ d$, instead of $b\ c$. When the attempt is made to restore the rejected fluid to the boiler, the compression would naturally cause the line $d\ k\ b$ to be retraced; but having removed the water of condensation from the engine separately, it cannot add, by its re-evaporation, to the tension of the steam under compression, and the latter must behave more nearly like a perfect gas, causing the line to take the direction $d\ l\ e$. The net result is the production of mechanical energy represented by the area $e\ b\ k\ d\ l\ e$, and the expenditure of an equivalent amount of heat energy, plus the amount of energy required to return the water of condensation to the boiler. Had, in this case, the steam been cut off at an earlier point in the stroke, as at e, the area $e\ n\ m$ would have represented the quantity of heat transformed into work. It is evident, that the more the steam is expanded, the greater will be the proportion of steam condensed, and the less the amount remaining to be compressed to boiler pressure, and the less the weight of steam required to be supplied to the engine per unit of work done. It follows that, to secure an engine combining high efficiency with small volume, it will be advisable to employ steam of high pressure, and to expand it as much as may be found practicable. The new type of engine can, probably, only supersede the common form when engineers can employ steam of very high pressure, and adopt much greater range of expansion than is now usual. Great velocity of piston and high speed of rotation are also essential in the attempt to make this revolution in steam engine construction a success.

XXII.—The term efficiency requires more accurate definition than is usually given it in works treating of heat engines. There are several distinct quantities to which the term is often applied. The *efficiency of the fluid*, by which should be understood the ratio of the quantity of work done by the working substance to the mechanical equivalent of its thermal contents at the instant of entering the cylinder of the engine, and which, measured by the quantity $\frac{Q - Q'}{Q} = E$, is often confounded with the *efficiency of the engine*,

which latter is the ratio of work of the engine during a given interval of time to the mechanical equivalent of the heat supplied to the engine in that time. The *efficiency of the boiler* is the ratio of heat delivered from the boiler in dry steam to the amount of heat developed in its furnace by the combustion of fuel. The *efficiency of the furnace* is the ratio of the amount of heat rendered utilizable by transfer to a boiler, by that furnace, to the amount of heat generated by the perfect combustion of the fuel supplied. The *efficiency of the engine* is also often taken as the efficiency of the whole combination of engine, with its fluid and with boiler and furnace working together. This latter is also often confounded with the efficiency of the fluid as well as with the efficiency of the engine proper. It is generally assumed that the theoretical efficiency of the steam engine, including its boiler, is limited by the efficiency of the fluid, and that, for example, the efficiency of an engine working between the limits of 800° and 600° on the absolute scale can have no greater efficiency than that measuring the efficiency of the fluid =, say, 0·25. That this is not the fact is seen when it is remembered that our ordinary calculation of the efficiency of the fluid takes no note of the temperature of the fluid supplied to the reservoir or of the method of disposal of rejected heat, which, as we have seen, is usually partly saved, and may be wholly restored.

Assume the limits of temperature and pressure of two engines to be the same, the upper limit being 90 pounds absolute pressure and the temperature 320° F., or 180° C., and the lower limit 2 pounds and 126·27° F., or 52·37° C., the working fluid to be steam, and one engine to be of the ordinary type, the other of the new type. Let both engines expand completely from the upper to the lower limit. First determine the value of $\frac{Q-Q'}{Q} = E$ for the common engine, taking Q as the net amount of heat supplied to each pound of steam by the fuel in the boiler, and Q' as the quantity rejected from the cylinder and discharged from the engine, assuming no losses to occur by conduction, radiation, or friction.

E is evidently the efficiency of engine and boiler working together, and its estimation should afford a basis for the calculation of the weight of steam required by the engine, and of water to be fed to the boiler. The efficiency of the furnace and calorific value of the fuel being known, the weight of fuel may then be calculated.

Taking the feed water into the boiler at a temperature of 110° F., which is a very usual temperature of feed, the total heat of steam supplied to the engine at a pressure of 90 pounds per square inch above a vacuum will be 1211·5 — 110 = 1101·5. The thermal contents of each pound of steam rejected from the cylinder at 2 pounds pressure, the temperature being 126·27, will be, if reckoned from the original temperature of feed, 1152·5 — 110 = 1042·5. The heat wasted with each pound of water so rejected, will be 126·27 — 110 = 16·27 thermal units.

The actual weights of steam and of the water rejected, per pound of steam supplied to the engine, may be readily calculated. It has been shown by Rankine that steam, expanding under the assumed conditions, and condensing, as it does, in a non-conducting vessel, preserves a relation of volumes and pressures which may be approximately expressed by an equation of the form $P\,V^x = C$, in which the exponent of the quantity V has a value exceeding unity. Rankine stated this value to be about 1·1111+; but it has been since determined by Zeuner to be more nearly 1·333+, which latter value will be taken as correct. It is confirmed by Cazin and Hirn.[1] The volume of one pound of steam at the temperature and pressure at which it enters our steam cylinder, is 4·72 cubic feet. The value of C is, therefore, $P\,V^{\frac{4}{3}} = C = 90 \times 144 \times \overline{4{\cdot}72}^{\frac{4}{3}} = 102{\cdot}611$. The volume of steam exhausted from the cylinder—expansion being taken to have been carried so far that the pressure at the opening of the exhaust valve is 2 pounds per square inch—must be $V = \overline{C \div P}^{\frac{3}{4}} = (102{\cdot}611 \div 2 \times 144)^{\frac{3}{4}} = 76{\cdot}53$. But the volume of 1 pound of steam at this pressure is 172·4 cubic feet. The quantity of uncondensed steam rejected from the cylinder, per pound of steam supplied, is, therefore, 76·534 ÷ 172·4 = 0·444 pound. The weight of water rejected is (172·4 — 76·5) ÷ 172·4 = 0·556 pound. The steam carries with it 1042·5 × 0·444 = 462·85 thermal units, and the water loses 16·27 × 0·556 = 9·05 units. The sum 471·90 units, is

[1] McCulloch. This value of x may have been here accepted on insufficient authority, however, as Zenner, in his treatise (French ed., p. 332), makes it 1·135, and Grashof makes it 1·140. Zenner also shows that the value of x is reduced by the addition of water to the steam. Laboulaye still insists, also, on the value 370 kilogrammetres, instead of 424, for Joule's equivalent, which, if correct, would modify the theory somewhat.

the total amount of heat wasted by rejection from the engine. The heat which has been utilized is $1101{\cdot}5 - 471{\cdot}90 = 630{\cdot}6$. The efficiency, E, is $(1101{\cdot}5 - 471{\cdot}9) \div 1101{\cdot}5 = 0{\cdot}57$, or nearly six-tenths.

As has been seen, had the working fluid been a permanent gas, the efficiency would have been one-fourth. The difference illustrates the superiority of the condensable vapor as a medium for conversion of heat into work. Assuming perfect efficiency, aside from the defect just estimated, this engine should require but $(1{,}980{,}000 \div 1101{\cdot}5 \times 772) \div 0{\cdot}57 = 4{\cdot}09$ pounds of steam, or about two-fifths of a pound of coal per hour and per horse-power. An actual engine, working steam in this manner, usually consumes at least five times this amount. The difference between the estimated theoretical and the actual efficiency, has usually been supposed to be much less, and it has been stated by the writer, as well as by other engineers, that the range left for improvement, by modification of the structure of the common engine, is much less than it is here shown to be.

The direction in which further improvement must take place in the standard type of engine, is plainly that which shall most efficiently check losses by internal condensation and re-evaporation by the transfer of heat to and from the metal of the steam cylinder. The condensation of steam doing work is evidently not a disadvantage, but, on the contrary, a decided advantage.

To secure this vitally important economy, it is advisable to seek some practicable method of lining the cylinder with a non-conducting material.[1] The loss will also be reduced by increasing the speed of rotation and velocity of piston. Where no effectual means can be found of preventing contact of the steam with a good absorbent and conductor of heat, it will be found best to sacrifice some of the efficiency due to the change of state of the vapor, by superheating it and sending it into the cylinder at a temperature considerably exceeding that of saturation. With low steam and slowly moving pistons, it is better to pursue the latter course than to attempt to increase the efficiency of the engine by greater expansion.

---

[1] This plan was adopted by Smeaton, in constructing Newcomen engines a century ago. Smeaton used wood on his pistons. Watt tried wood as a material for steam cylinder linings. That material is too perishable at temperatures now common, and no metal has yet been substituted, or even discovered, which answers the same purpose.

Increasing steam pressure and expanding to a greater extent will give theoretically slightly increased economy. Repeating the calculation made above, using as constants the temperature, volumes and pressures of steam entering the cylinder at 250 pounds, and expanding down to the same point, it will be found that the gain in efficiency is but a few per cent. It is not in that direction, therefore, that we are to look for important improvement in the use of the ordinary type of engine. There seems no alternative but to attempt to alter it into an engine of our new Type B, and look for the discovery of an efficient non-conducting lining material which shall enable us to save the, probably, thirty per cent. of heat supplied which is transferred to the condenser by internal condensation and re-evaporation.

XXIII.—The question whether such an engine as that which has here been described as type B can be made practically successful, can only be answered after careful and intelligent experimental investigation. The advantages promised by the results of theoretical investigation, will be greatly modified by conditions unavoidably introduced in the construction and operation of the machine. Some of these conditions may be anticipated, and their effect upon the efficiency and upon the success of the engine in other respects may be indicated in advance. It is even possible that a rough approximation may be made in estimating its real practical value.

The essential requisites of a successful type of engine are: safety; economy; durability; simplicity; compactness, and a moderate first cost.

Safety may always be secured by intelligent design, good material and workmanship, and skilful management. The new type is not especially liable to objection on the score of danger, except so far as it may prove essential to its success to work at exceptionally high pressures; but as pressures of 1000 and 2000 pounds were controlled without accident, forty years ago, by Perkins and by Albans, it is not to be anticipated that danger will necessarily be incurred at pressures far exceeding those in general use to-day, yet far within the limit already attained. The durability of the engine will also be determined by the same conditions as its safety, and is to be assured in the same manner. The actual economy to be secured by its adoption is largely determined by the size which it may be found necessary to give it; for its losses will be almost wholly due to friction. In simplicity, it is not likely to

compete with the common engine, since it must be fitted with some apparatus for compressing the steam to be returned to the boiler. It is not improbable, however, that the new type may be yet given a form in which it may compete nearly as successfully, in this respect, with the ordinary engine as has the compound type of the latter with the older forms.

To determine the probable size of the engine of Type B, it need only be remembered that, as it must expend, in returning to the boiler its unutilized heat, a proportion, $1 - E$, of the power produced at each stroke, it must, when running at the same speed, work off a greater volume of steam in doing the same work, in the proportion $1 \div E : 1$. But the larger engine will be subjected to frictional resistances which will be similarly increased, and this, in turn, will exaggerate the size of engine and the losses of efficiency. Replacing an engine of the old form, having an efficiency of 20 per cent., by an engine of the new type, it will be necessary to either make the latter of five times the piston displacement of the former, per stroke, or to run the new engine at five times the speed of piston of the old. It should be the endeavor to make the change in the last named of the two ways, not only as a matter of economy of first cost, but as a means of reducing losses of pressure by internal condensation and re-evaporation. It is evident that such losses of pressure do not affect the estimated economy of the engine, since, however much heat is thus caused to be rejected from the cylinder, it is all saved and restored. The higher the steam pressure used, and the higher the efficiency due to increase in the amount of heat converted into work, the more favorable do the actual conditions of use become to the new engine.

Assuming an engine of the proposed type to have an estimated efficiency of fluid of 50 per cent., it must be made, at the same piston speed, twice the size of the engine of the common form. To allow for increased frictional and other losses, an addition in enlargement of probably 25 per cent. must be calculated upon. The theoretical cost of the horse-power will be about 5 pounds of steam per hour. The losses of heat by conduction and radiation, which, in the common engine, may be taken as 10 per cent. as a maximum, will become 20 per cent., and will bring up the consumption of steam to 6 pounds per horse-power developed in the cylinder. The resistance due to friction, which may also be taken at 10 per cent., will be doubled also, and this will raise the expenditure of steam to above 7 pounds. We may take

as the probable consumption of heat in such an engine, per hour and per horse power, very nearly 8000 British thermal units. With good boilers, this will call for the combustion of about three-quarters, or four-fifths, of a pound of good fuel—about one-third the amount demanded by the very best engines ever built for transatlantic steamers, and one-quarter as much as is usually consumed with very large marine engines of the now popular compound type. But the advantage to be secured by the adoption of this type becomes greater with higher pressures, and will therefore be likely to appear greater and greater continually. With what would now be thought exceedingly high steam, and with vastly increased piston speeds, such as will almost certainly be adopted in the future, the new type will appear a very much more promising plan than it now does.

The now standard engine drives a steamship across the Atlantic with a consumption of 1000 tons of coal; the new engine should do the same work on 250 tons. It should occupy but little more available space in the ship, but would weigh twice as much unless the piston speed were correspondingly increased. The greater weight of engine would be vastly more than counterbalanced, however, by the reduction of space and weight devoted to boilers and coal-bunkers, to one-third or one-fourth their present capacity. If this type of engine should prove to be available with steam pressures that are soon to be found readily controllable, it is certain that it will be even more advantageous for marine purposes than for use on land, where these reductions of space and weight are of less importance. Even its application to locomotives would not be thought impossible.

XXIV.—Several engines of this type have been planned by the writer, in all of which the rejected heat is returned to the boiler.[1]

Any expert mechanical engineer will readily devise many methods by which the standard forms of steam engine may be modified and converted either into illustrations of this Type B, or into engines of Class 2, in which the rejected heat is very nearly all restored to the boiler. When this possible "engine of the future" is likely to be introduced, if at all, can be scarcely even conjectured. It seems evident that its success is to be secured, if its introduction is attempted,

[1] The idea first suggested itself to the mind of the writer in 1858-9, when at Brown University, and while designing a peculiar form of "drop cut-off engine," which was designed to work with exceptional economy. The plans then conceived have gradually assumed a different shape, but still embody the essential principles here outlined.

by the adoption of high steam pressures, of great piston speeds, by care and skill in design, by the use of exceptionally excellent materials of construction, and by great perfection of workmanship and intelligence in its management. There seems no tangible obstacle to its introduction; but engineers who have seen the slow progress of the compound engine and of surface condensation in marine construction will anticipate no very rapid progress here.

Experiment and experience will probably lead gradually to the general and safe employment of greatly increased steam pressures and very greatly increased piston speeds, and will ultimately reveal and remove all those difficulties which must invariably be expected to be met here, as in all other attempts to effect radical changes, however important they may be. We are continually learning that the use of steam as a medium for transformation of heat into mechanical energy is more advantageous than it had been supposed. The corrected estimates of the efficiency of the steam engine given above, show it to be capable of far more perfect utilization than generally accepted authorities had supposed possible. It is not improbable that even these estimates give a very inadequate idea of the true efficiency of the perfect steam engine. We know almost nothing of the physical properties of steam which are mostly concerned in its utilization in heat engines at the high pressures which we know are attainable; and it is impossible to say that the modifications of specific heat and of pressures at such high temperatures may not be such that it may prove a vastly more efficient working substance for the heat engine, at such temperatures and pressures, than we are led to consider it from our knowledge of its properties at the now usual working pressures.

Stevens Institute of Technology,
Hoboken, N. J., *April*, 1877.

Addendum.—The probability of the successful adoption of the type of heat engine described in the above paper, is evidently largely dependent: first, upon the correctness of Rankine's or of Zenner's determination of the value of the exponent in Poisson's formula, $P V^{x} = C$; secondly, upon the possibility of obtaining a high value of that exponent in actual work. It is evident, that if Rankine's value, $\frac{10}{9}$, were correct, it would be quite out of the question to expect that an engine can ever be built in which the magnitude of the machine should be so far reduced, in proportion to power

developed, as to insure the success of this plan. If the larger value, $\frac{1}{4}$, is correct, it is equally evident that success is possible, even if not extremely probable, assuming that the process of internal condensation and re-evaporation may be checked.

The writer has received, since the above was written, a statement of the results of experiments upon a quick-running portable engine made by Mr. J. C. Hoadley, to determine the value of the exponent, x. In that instance Mr. H. finds the value of x to be 1·247, or nearly $\frac{1}{4}$, in an engine which was not constructed with any special provision for checking this kind of loss, except so far as it is reduced by high speed of piston and frequent reciprocation.

This may, probably, be taken as another proof of the erroneousness of Rankine's value, and the more probable accuracy of Zenner's, and as indicating the possibility of, at some future time, securing a nearly perfect working of the steam in the cylinder, thus attaining, approximately, the perfect efficiency of the new type of engine.

R. H. T.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[1]

By Dr. A. W. Hofmann.

From the *Chemical News*.

[Continued from Vol. lxxiv, page 269.]

If the Rhenania Chemical Works was willing to sell its two platinum vessels, one of which has been procured only a few years ago, while the other has been in use for twenty-one years, and has undergone repeated repairs at the price of 810 francs per kilo., the account would show a consumption of 0·972 grm. of platinum per 1000 kilos. of sulphuric acid, or an outlay on platinum equal to 1·616 francs, or 1·29 marks (not quite 1·3 d.) per 1000 kilos. of acid at that strength.[i]

---

[1] "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

[i] As regards the question what method of concentration is the more economical, the following information has been received by the editor from P. W. Hofmann, of Wock-

In general the acid at Hautmont, and at Stolberg, was free from nitrogen compounds; if nitrous acid was found on testing with indigo, a little ammonium sulphate was added to the acid in the lead pans, according to the suggestion of Pelouze.

The two firms who exhibited platinum stills at Vienna, were Desmoutis, Quenessen & Co., of Paris, and Johnson & Matthey, of London. The apparatuses differ in certain details. The English firm employ double syphons and cooling worms, whilst the French make use of a long single syphon. The capital which conducts away the weak acid slopes towards the body in the English apparatus, whilst in the Parisian it is bent away in the opposite direction. The English arrangement, by reason of its reflux, yields less weak acid, but at the same time also a smaller quantity of concentrated acid than does the French.

The opinions of manufacturers concerning the stills of the two firms, were upon the whole equally favorable. The English acid makers obtain their platinum stills for convenience' sake generally from London, whilst many Continental manufacturers remain in connection with Desmoutis, Quenessen & Co., on account of the rapidity of transport in case of repairs.

Both the stills exhibited in Vienna, had a syphon of a new construction, one of whose legs, placed within the still, has a lateral aperture at the same level with the heating flues. By means of this arrangement, the acid in the apparatus can never fall below the level of the upper angle of the flue. The sheet platinum is therefore constantly covered by the liquid, whilst on the old principle the workman was not able to observe the level of the acid, and the syphon could run off the contents of the still to such an extent, that the furnace-gases could play over and damage the dry metal.

The arrangement in the apparatus of Desmoutis, Quenessen & Co., was proposed by the author.[1] In order to prevent the evacuation of

---

[1] R. Hasenclever, *Ber. Chem. Ges.*, vii, 502.

lum. At Dieuze, where 2500 kilos. of sulphuric acid are daily concentrated to 66° B. in glass vessels, the cost per 1000 kilos. is as follows:—

Coal, 200 kilos.,	4 marks
Labor,	3 "
Breakage,	1 "

If the precaution is observed of changing all the retorts every six weeks, whether damaged or not, breakage can be almost entirely avoided, and the cost for glass reduced to about 75-100 of a mark.—A. W. H.

the apparatus below the desired level, the lateral orifice in the syphon is connected with an air-pipe, which plunges in from above. It is thus contrived that the syphon always draws off sulphuric acid from the deepest part of the apparatus, whilst a simple lateral orifice in the syphon, without a tube opening upwards, would, during regular working, produce an influx of sulphuric acid into the syphon at this place. To prevent the acid spurting out during boiling, a funnel with a movable cover is fitted to the top of the air-pipe. If it is wished to empty the apparatus entirely, the aperture of the funnel is closed with a plug, which is not kept by the workman in charge.

In the arrangement adopted by Johnson & Matthey, for the same purpose, a reciprocating cock is introduced into the air-pipe above, so as to allow the apparatus to be emptied. It is probable that the workman will generally close this cock, for when the syphon is run out, he has the trouble of filling it again, before resuming work. He operates then with an arrangement which acts exactly like a common syphon, as when the cock is shut, the lateral orifice does not communicate with the atmosphere.

A. de Hemptinne[1] constructed an apparatus for concentrating sulphuric acid down to 1·84 specific gravity under reduced atmospheric pressure without the use of glass or platinum. The apparatus is said to be in operation near Brussels, but is little employed elsewhere.

Baist and Rœssler, of the Greisheim Chemical Works, employ experimentally a modified platinum apparatus, as patented by Johnson & Matthey. In this arrangement only the lower part of the still which contains the acid, and is exposed to the furnace gases, is made of platinum, the dome being constructed of lead. This apparatus does not cost half as much as an ordinary platinum still, but in practice it requires frequent repairs, since the lead is heated too strongly from below, and is too heavily weighted above by the refrigerating liquid.

Faure & Kessler, sulphuric acid manufacturers, at Clermont-Ferrand (Puy de Dome), have sought to improve the construction of the platinum and lead concentration apparatus. This process is described in a pamphlet, "Notice sur les Appareils a Cuvette pour la Concentration à 66° B. de l'Acide Sulphurique."

---

[1] A. de Hemptinne, *Dingler's Polyt. Journ.*, ccv, 419; *Wagner's Jahresberichte*, 1876, 243.

The acid is heated in a very flat platinum pan, of about 70 centimetres diameter. Over this pan is a very roomy lead chest, in which is condensed the weak acid which distils over. This construction affords a greater prospect of durability than the dome resting directly upon the pan, and the apparatus is said, in fact, to be capable of working for months without repairs. The inventors give in their pamphlet a comparative scale of cost, and mention as the principal advantages the following:

1. Decrease of first cost in the proportion of 300 to 350 per cent (?).
2. No wear and tear of platinum.
3. Decrease of 90 per cent. of the loss in case of accidental injury to the still.
4. Economy of fuel.
5. Reduction of labor to the extent of 30 to 60 per cent.
6. Total abolition of the stoneware jugs, used for filling the apparatus, and consequently no loss from their breakage.
7. Freedom from danger.
8. Greater regularity.
9. Reduced wear and depreciation of platinum, one-twentieth of ordinary amount. (But see No. 2 above.)
10. Great convenience for repairs.

An apparatus of Faure & Kessler's, costing 15,000 francs, is said to yield in twenty-four hours about 2500 kilos. of sulphuric acid at 66° B. An apparatus of the same power, entirely of platinum, can be had from Desmoutis, Quenessen & Co., for 30,000 francs, even if the platinum costs 1000 francs, and not for 45,000 francs, as assumed in the pamphlet. The first cost, supposing Faure & Kessler's system to hold good, is only reduced 50 per cent.

The advantages Nos. 2 to 10 cannot be taken into consideration: stoneware jugs can be dispensed with in an ordinary apparatus, and the depreciation of the platinum pan must be increased, since in the ordinary construction it is precisely the lower part which suffers, whilst the weight of the dome and syphon remains approximately constant.

[To be continued.]

MUSIC OF THE MOONS.—II.

By Pliny Earle Chase, LL. D.

[Continued from Vol. lxxiv, p. 354.]

The harmonic series, of which Mars and its satellites form a part, seems to have been established before the ring of greatest nebular condensation—the ring of which Earth was the centre—was broken up. In the solar system, as well as in the group of densest planets, the number 3, which represents the uneven harmonics of an organ-pipe, as well as the oscillatory divisions of a linear pendulum, holds a prominent place. For we find, at the outset, the following approximations to important nebular centres:

$3^8 = 9^4 =$		6561	6518 =	Neptune's secular aphelion.
3^7		2187	2222	Saturn's secular aphelion.
3^6	9^3	729	735	Cybele.
3^5		243	229	Earth's secular aphelion.
3^4	9^2	81	83	Mercury.
3^3		27	. .	
3^2	9^1	9	. .	
3^1		3	. .	
3^0	9^0	1	1	Sun's semi-diameter.

This accordance is the more significant, because Saturn's secular aphelion is at the centre of the ring of secondary condensation, which extends from Sun's surface to Uranus's secular aphelion.

"Bode's Law,"[1] was based on successive differences of $2^0 \times 3$, $2^1 \times 3$, $2^2 \times 3$, etc. If we subtract 1 from each of the theoretical Bode numbers, and divide the remainders by 3, the quotients are 1, 2, 3, 5, 9, 17, etc., each of the quotients, except those for Venus and Neptune, being of the form $d_{n+1} = 2\,d_n - 1$; the dense-belt series being of the form $d_{n+1} = 3\,d_n - 1$.[ii]

In the infinite series, $\frac{1}{2} + 3^{-\infty} + 3^{-\infty+1} + \ldots 3^{-1} + 3^0 + 3^1 + 3^2 + \ldots$, successive sums, in the neighborhood of unity, give the following accordances:

---

[1] This Journal, Sept., 1877, p. 162.

[ii] *Ibid.*, Nov., 1877, p. 352.

Sums.		Harmonic Divisors.	Quotients.	Observed.	
$\frac{1}{2}$	=	$\frac{1}{2}$	27·38	27·00 = 3^3.	
$+ 3^{-\infty}$		.	.	.	
+ .		.	.	.	
+ .		.	.	.	
$+ 3^{-4}$		$\frac{14}{27}$	26·40	26·20	Extreme major-axis.
$+ 3^{-3}$		$\frac{5}{9}$	24·64	24·39	Mean major-axis.
$+ 3^{-2}$		$\frac{2}{3}$	20·53	20·68	Extreme secondary radius.
$+ 3^{-1}$		1	13·69	13·69	Nebular radius.
$+ 3^{0}$		2	6·85	6·85	Deimus.
$+ 3^{1}$		5	2·74	2·73	Phobus.
$+ 3^{2}$		14	·98	1·00	Semi-diameter of Mars.
$+ 3^{3}$		41	·33	·33	Oscillatory centre.
$+ 3^{4}$		122		120·56	Moon's major-axis.
$+ 3^{5}$		365		365·26	Terrestrial acceleration.
$+ 3^{6}$		1094		1096·20	Jupiter's semi-major-axis.

The "Extreme major-axis" is the major-axis of an ellipse, connecting the inner planets of the two outer two-planet belts at the secular aphelia of Uranus and Jupiter; the "Mean major-axis" is the sum of the mean distances of Uranus and Jupiter; the "Extreme secondary radius" is Uranus's aphelion radius, or the semi-diameter of the ring of secondary condensation; the "Nebular radius" not only represents the theoretical incipience of Mars's nebular condensation, but it also corresponds, almost precisely, with the sum of the secular perihelia of Jupiter (4·886) and Saturn (8·734), in units of Earth's semi-major-axis—the secular perihelion being the time of greatest orbital *vis viva*; "Moon's major-axis" is also Earth's "Nebular radius;" the "Terrestrial acceleration" represents the theoretical increase in the angular velocity of Earth's rotation, since its rupture from the central nucleus, or the ratio of its day to its year; "Jupiter's semi-major-axis" is measured in units of Sun's mean perihelion distance from the centre of gravity of Sun and Jupiter.

The sum of the infinite series, to and including 3^{-3}, is $\frac{4}{9}$, which represents the ratio of *vis viva* between undulatory velocity and the velocity of the particles of a medium constituted according to the Kinetic theory.[i] Alexander has shown the importance of that ratio in planeto-taxis,[ii] and I have shown that it represents "centres of

[i] Maxwell and Preston, *Phil. Mag.*, June, 1877.

[ii] "Smithsonian Contributions," 280.

explosive oscillation," or the centre of secondary oscillation between the primary centre of oscillation and the centre of gravity, in a homogeneous line of particles ($\frac{3}{4} - \frac{3}{8}$ of $\frac{1}{6} = \frac{5}{8}$). Adding the next term of the series, we get $\frac{3}{4}$, which represents the centre of linear oscillation. Neptune's major-axis (60·06) is, within $\frac{1}{10}$ of 1 per cent. ($3^4 - 3^3 + 3^2 - 3^1 = 60$) times Earth's mean radius vector.

These harmonies embrace orbital radii of the largest five planets of the solar system, of the inner planets, and of the asteroidal belt, together with nebular-, satellite-, and planetary-radii, for the outer and the middle planets in the theoretically primitive central belt, or the belt of greatest condensation. Can any interpretation be rightly put upon such a chain of harmonies, which does not recognize the fundamental laws of harmonic oscillation and harmonic design?

Neither of Mars's moons is of sufficient magnitude to cause any great perturbations. To this fact, perhaps, as much as to the proximity of the density-centre, we may attribute the regularity of the Mavortian system. In the solar system, as we have seen,[1] the preponderating mass of Jupiter sets up a new order of differences in the harmonic denominators; and we may find probable indications of similar influence in some of the satellite systems, and in the elementary spectra.

In the satellite system of Uranus, if we take the semi-major-axis of the outer satellite as the common numerator (22·75), we find the following harmony:

Satellites.	Distances.	Denominators.	Theoretical.
Oberon,	22·75	1·000	1·000
Titania,	17·01	1·337	$1{\cdot}343 = 1 + 2\,a$
Umbriel,	10·37	2·194	$2{\cdot}199 = 1 + 7\,a$
Ariel,	7·44	3·058	$3{\cdot}055 = 1 + 12\,a$
Semi-diameter,	1·00	22·750	$22{\cdot}750 = 1 + 127\,a$

In the Saturnian system there is a slight uncertainty in the satellite elements, except in the case of Titan, whose orbit was well determined by Bessel. It will be seen that Titan's great mass introduces a secondary harmony. The following harmonic denominators are based upon relative mean distances which would represent the orbital times, as furnished by Professor Hall:

[1] This JOURNAL, Sept., 1877, p. 167.

Satellites.	Times.	Denominators.	Theoretical.	
Japetus,	79·3292[d]	1·000	1·000	
Hyperion,	21·3113	2·402	2·397 =	$1 + a$
Titan,	15·9454	2·914	2·920	$1 + b$
Rhea,	4·5175	6·756	6·760	$1 + 3b$
Dione,	2·7369	9·436	9·384	$1 + 6a$
Tethys,	1·8878	12·087	12·179	$1 + 8a$
Enceladus,	1·3702	14·966	14·974	$1 + 10a$
Mimas,	·9425	19·206	19·166	$1 + 13a$
Semi-diameter,		64·359	64·360	$1 + 33b$

It is well to notice that b (1·920) is very nearly the square of a (1·397).

In the column of times, Japetus, divided by Titan, is nearly 5; Hyperion, by Rhea, 5; Dione, by Enceladus, 2; Tethys, by Mimas, 2; Titan, by Rhea, $\frac{7}{2}$; Rhea, by Dione, $\frac{5}{2}$; Hyperion, by Titan, $\frac{4}{3}$; Hyperion, by Dione, 8; Hyperion, by Mimas, $4\frac{5}{2}$; Titan, by Mimas, 17.

The satellite system of Jupiter, our Sun's "companion star," exhibits harmonies of distance, time and mass. The mean distance of the outer satellite, Callisto, is 3^3 semi-diameters of its primary (26·9984). Using this as a common numerator, we find that the other satellites are phyllotactically, as well as harmonically, arranged:

Satellites.	Distances.	Denominators.	Theoretical.	
Callisto,	26·9984	1·000		
Ganymede,	15·3502	1·759	1·731 =	$5a$.
Europa,	9·6235	2·807	2·769	$8a$.
Io,	6·0485	4·464	4·500	$13a$.
Semi-diameter,	1·0000	26·998	26·998	$78a$.

The harmonies of time and mass are as follows:

Satellites.	Times.	Theoretical.		Mass.	Theoretical.	
Callisto,	16·689[d]	16·684 =	$28t$	4266	4403 =	$\frac{1}{2}m$.
Ganymede,	7·155	7·150	$12t$	8850	8806	$1m$.
Europa,	3·551	3·575	$6t$	2324	2202	$\frac{1}{4}m$.
Io,	1·769	1·788	$3t$	1733	1761	$\frac{1}{8}m$.

A DECIMAL GAUGE FOR SHEET METAL AND WIRE.

By Robt. Briggs, C. E.

Various standards of measurement, designated as gauges, which are a series of notches of several widths made in the edge of a metal plate, the widths of the notches bearing some relative proportion of gradation from small to large, have become established by time and customary local or trade usage of English metal workers or dealers. These gauges are purely arbitrary, both in dimension and relative proportion of the notches. In regard to dimension, they do not refer to any other unit of measurement—each notch is an original dimension of itself—nor do they have any definite relation to weights of sheets of given superficies, or of wire of given lengths; so that to the unpracticed mechanic of the schools or books, they seem to be "thoroughly senseless," to quote the words of a very intelligent technical author and compiler. As for relative proportion of the gradation, it can be said, after close examination, that there *is* an evident attempt to have the differences of thickness which follow each other, in some manner proportionate—they are the *guess* of the workmen at a geometric proportion of dimension.

The gauges were of local origin at first, and each locality where sheet metal or wire was made or worked, and even each kind of sheet or wire, as iron, steel, copper, brass, silver, etc., had its own trade gauge. This general development of the system of gauges may be fairly claimed to support the "sensibility," if not desirability or necessity, for their existence. Of late years the gauge known as the Birmingham gauge has been perpetuated with much care, and with general exactness of repetition, by the firm of Messrs. "Stubs," of Warrington, England, and has gradually come into use in supersession of most of the other gauges. An especial gauge for brass sheets or wire has held its place in England against the encroachment of the "Stubs" Birmingham gauge, to some extent at least; while in the United States a so-called American gauge has nearly supplanted the brass gauge, and has met with some use in the measurement of iron sheets or wire.

The gauges, all of them, refer to small dimensions relative to the inch, so small that the dimensions cannot be measured by any rule,

even one with sixteenth divisions of the inch upon it. With finer divisions, say hundredths of an inch, which have been attainable within the past twenty years, a comparison of a callipered dimension has been possible to the limit of exactness which the $\frac{1}{100}$ of an inch will give. But this degree of accuracy is much below the wants of the workman, who demands that the measurement of thickness shall control the weight of the plate per square foot, or of wire per lineal foot, and even the hundredth of an inch becomes of large value in the differences of the lighter gauges.

There is a real necessity for the *gauge* as a means of measurement, and, more than this, there is a *necessity that the division should not follow the ordinary notation of figures.* An examination of the various gauges of old—the Birmingham iron (which is the present "Birmingham"), the Birmingham brass, the Lancashire, the rod gauges—shows that there is a rough approximation to the scale of proportionate dimension throughout them all. The fact is made evident that the workman desired that the next number to any given two numbers or pair, above or below, should be greater or less in thickness in proportion to the increase or reduction which had been established in making the differences of the pair assumed. In other words, the workman did not require a uniform increase as 1, 2, 3, 4, 5; but one as 1, $1 + \frac{1}{4}$, $1\frac{1}{4} + \frac{1}{4}$ of $1\frac{1}{4}$, etc.; he *required* not an arithmetic, but a geometric, proportion. Thus, for the purposes of trade, let it be supposed that plates $\frac{10}{100}$ of an inch are wanted for some one use, it is evident that $\frac{8}{100}$ might be a suitable dimension to meet a similar demand for a less requirement of strength or thickness, and that, in practice, intermediate dimensions might not be demanded as merchantable; while descending in thickness by units, until $\frac{2}{100}$ are reached, it is apparent that several merchantable thicknesses ought to exist between this dimension and $\frac{1}{100}$, or half its thickness; and, pursuing the argument *ad absurdum*, it cannot be argued that no metal ought to be kept as an article of sale less than $\frac{1}{100}$ of an inch in thickness, because the numbers run out in units of hundredths of an inch at this point. In mathematical language, the gauges are not expressed in arithmetical notation, but in an exponential one, and the numbers of the steps represent $a\,m^N$, where a is a co-efficient of length or of weight, m is the common ratio or modulus of the system, and N is the characteristic or exponent assumed in any instance.

This law of the formation of a scale of gauges was fully recognized some twenty years since, by Messrs. Brown and Sharpe, of Providence, R. I., who then proposed to correct the discrepant proportions of the Birmingham gauge, by establishing a regular proportion of the 39 successive steps between the 0000 and 36 of that gauge. In this case the value of 0·46 inch has been taken as that for 0000, or the largest dimension of the scale, then by successive uniform decrements, each number following being derived by multiplying the former one by 0·890522 (or deducting 10·9478 per cent.); the final value for number 36 is reached at 0·005 inch, which figure corresponds to number 35 of the Birmingham gauge. This gauge was named the "American" gauge, and has been largely made by the proposers.

But this gauge, with all its correctness of system of proportionate parts, has met with little favor from practical men, and none at all beyond the limits of the trade influence of its makers, whose reputation for accuracy of workmanship in instruments of measurement in other regards, as well as in furnishing these gauges of constant and unimpeachable exactness, has commended a favorable introduction to all American mechanics. The old gauge, to those who use it most, is a scale of dimensions which they think in, as positively as an Englishman thinks in English; its differences are near enough proportionate in the limits of five or six steps to serve to think about, in giving dimensions to a vessel of any kind, and even the irregularities are fixed in the mind so that the error in proportion is measurably removed. A new scale of figures, which in some places differs one or two numbers from the old one, becomes to these men a source of confusion of ideas. To such workmen or users no substitute gauge would commend itself which did not present more advantage than the sentimental one of exact sequence in proportion that had been attained by the adoption of a rate of proportion altogether beyond his ability to comprehend.

The requirements of a gauge, however, have changed in the last fifty years. Uniformity, as one, has been satisfied in degree by the conflict of local gauges, in which it may be presumed that the "fittest," the Birmingham, has survived—although it may be possible that the Birmingham gauge owes its victory to the skill of its advocates and makers, and not to especial fitness. Accuracy has been secured by careful measurement of the gauge spaces, and comparison to the

standard linear units of the land. Elaborate tables give the value in inches and decimals of the several dimensions, and also give the exact computed weights of superficies, sheet metal, or lengths of wire of the several metals of commerce.

The requirement of a uniform proportionate gradation of the steps of the gauge may be fully admitted, but whatever proportion is adopted, it should be a simple one. The great use of the gauge to-day is for the purpose of estimate—for calculating the value of given superficies or lengths in weight of material, or *vice versa*, if it can be made more convenient for this end by a new notation or new division of parts, then a change can be advocated and certainly in the end effected.

There are some results from any gauge which must be tabular. The requirement of proportionate sequences leaves but one set of numbers in our arithmetic notation, which will conform; this set of numbers is 1, 10, 100, 1000, etc., where each number is ten times the one before it. This difference is out of the question, and any other proportionate difference leads to interminable figures. It must be accepted, therefore, that with any modulus or difference of ratio between any two steps of the gauge, there can be but *two* points in the scale where an even number can occur, or where any assumption of an arbitrary value will be possible, and if the modulus is established with any rational or aliquot number, there can be but *one* single value in the whole scale which can be expressed in even numbers, or arbitrarily assumed for any value. The values of a series of relatively proportionate sizes must therefore be expressed by decimals, and be derived for practical convenience from a table, and not deduced by special calculation each time. Again, the complicated relation of our English units of weights and measures, together with the various specific gravities of the metals to be gauged, give tabular values for weights which derive exactness only from long extension of decimals, and are utterly devoid of simple expression.

The proposed Decimal Gauge is based upon the successive reduction of an assumed unit of dimension by one-tenth, or, what is the same thing, of successive increase of its divisions by one-ninth.

The establishment of the unit which should be the base of this scale, has been duly considered. This unit has the characteristic number of zero (0), and observation shows, that supposing it is advisable to have the new gauge conform in the main with the Birmingham

gauge, then one centimetre = 0·3937079 inches, very satisfactorily fulfils this demand. This value differs one number from the Birmingham one, but this difference gradually disappears in the irregular proportion of the Birmingham gauge, until at No. 8 the two systems nearly coincide. The coincidence continues for 6 numbers to No. 14, after which the new gauge becomes thicker than the Birmingham, with smaller differences, so that three more numbers are needed in the decimal gauge to cover the same range of thickness.

At this point it is only necessary to refer to the scale and to the tables of comparison. So far as relative difference between pairs of numbers is concerned, inspection of the column of Birmingham gauges in Table I, will show that between Nos. 000 and 4 – 6 spaces, the decrease for each size is $\frac{1}{10}$, nearly, and the same between Nos. 8 and 12 – 4 spaces, and also the same between Nos. 20 and 30 – 10 spaces; so that 20 spaces out of the 39 follow, with close approximation to exactness, the rule of uniform reduction of one-tenth. The ideal perfect gauge of the workman may be fairly accepted as having this ratio of differences! The adoption of this ideal involves the regulating of values which the true decimal gauge effects, when the substitution of new values in the scale at the places of discrepancy necessitates three or four more numbers.

The plate accompanying this paper, represents the Decimal, Birmingham and American gauges graphically, showing the irregularities of the Birmingham gauge as derived from figures given in the text books (the authority of which figures is "Holtzapfel's Mechanical Manipulation," 1846), but some allowance must be made for inaccuracy of measurement of the smaller gauges, where the decimal values are carried out to only two, and below No. 32 to only one figure. The enlarged diagram on the plate, gives in dotted line a more correct view of the Birmingham gauge from No. 30 to 36.

Returning to the question of value to be assumed for the unit of thickness, there was another metric value which presented some points of merit. The solid volume of a sheet measuring 1 square metre, and having a millimetre of thickness, is equivalent to a cubic decimetre, again represents the litre or measure of capacity (= 1·05656 American quarts = 0·88025 English quart) and the kilogramme of water (= 2·204737 avoirdupois pounds). If the millimetre were taken for the unit, the "0" of the gauge would be about No. 20 of the Birmingham gauge. From this unit the numbers would range upwards and

downwards; in the upward direction "plus" 23 would be a little less than the Birmingham 0000 in thickness. With this unit of thickness as the starting point, the weight of sheets of iron, steel, copper, brass, or other metal corresponding to it, per metre square of surface, represents the specific gravity of the material. That is, as a litre of water weighs one kilogramme, the metre square of iron of one millimetre in thickness, *having the same cubic volume*, weighs 7·77 kilogrammes, and with other metals the same relationship to the comparative weight of water for sheets one metre square by one millimetre in thickness, exists. The objection to this value is the disturbance of the relationship of numbers to thicknesses of sheets, or diameter of wires, which is now so positively fixed in the minds of the "trade." It makes no real difference whether the scale of figures runs up or down. No unit can be taken which will be so large or so small that it can be adopted as a starting point from which to proceed upwards or downwards only. Certainly the thickness of 0·039 of an inch is not so small that negative or descending numbers will not be a necessity, while the number 0·39 of an inch is in fact so large, that, as a scale of numbers, the sizes above zero are not to be classed as merchantable. This last qualification being one of the main conditions of sheets and wire, which are measured by a gauge. And if the unit be taken at a centimetre in place of a millimetre, the relation of weights of a metre square of sheets to specific gravities is yet preserved to all intents and purposes, being only increased by multiplying by ten; the metre square sheet of iron, which has the thickness of a centimetre, weighing 77·7 kilos., while its specific gravity is 7·77.

On the whole, the adoption of the centimetre as the unit of thickness, which shall represent zero in the exponential scale of numbers, seems to meet at once the demands of conformity with natural constants, and also with the habitual *thought* of the metal and wire workman.

A decimal progressive scale could be made in either of two ways—it can either increase or decrease by a decimal rate. Thus, if one-tenth is added each time to a series of numbers, the retrograde steps will be the deduction of one-eleventh, and on the other hand, if one-tenth be deducted each time, to form a similar series, the increase of each number will be one-ninth added to that below it. Either of these ways is equally advantageous in use for computing, but the

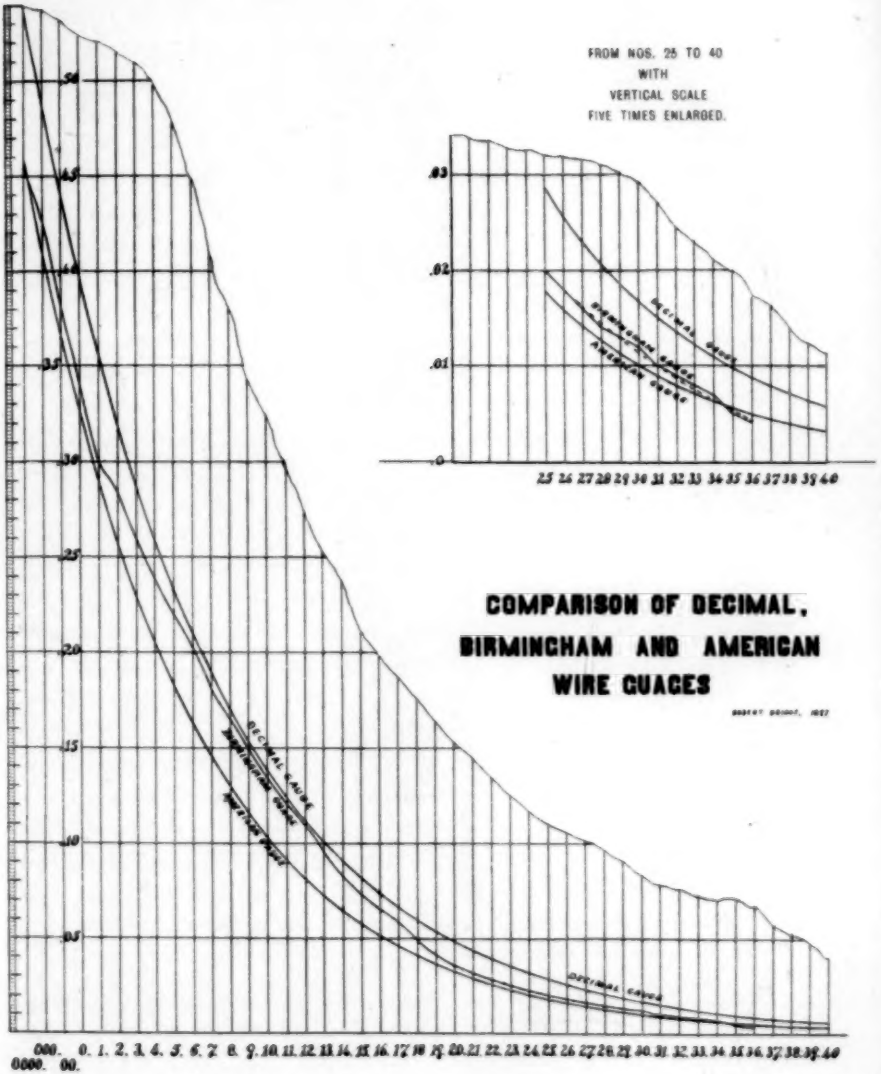
one-tenth of addition will give nearly 24 steps in passing from one to ten, while the one-tenth of deduction gives nearly 22 steps in passing from ten to one. This small difference of number of steps would have little effect in the decision as to which system to follow, except that the Birmingham gauge has from 18 to 20 steps in the passing from any of its values to those ten times as great. [The "American" gauge gives very nearly 20 steps in this change of values, but as it avoids one-ninth deduction (or one-eighth addition) by the least of difference, so also it avoids the equal stepping off of the space of two-fold increase with 20 steps by a small fraction.] As it has been shown before, that the Birmingham gauge has a large portion of its spaces at one-tenth deduction, and as 22 steps in ten-fold increase or decrease most nearly correspond to the known gauge of commerce, it would appear that $\frac{9}{10}$ is a more proper basis for the new gauge than $\frac{1}{10}$, and the plate and tables follow $a\,(\frac{9}{10})^N$ as the most suitable base.

It remains to be shown what advantages are to be derived from the adoption of this gauge. It will give a scale of proportionate dimensions for all the practical sizes of thickness of sheet metal and diameter of wire; which scale can be extended upwards or downwards to cover any possible future demand. The American gauge already does this, so far as uniform proportion is concerned, equally well. But the decimal gauge gives a numerical proportion which is easily remembered and readily used in computation. In sheet metal especially, it is the constant requirement upon the workman to estimate for weights. Having calculated with much care the weight of a vessel or tank, a boiler or cauldron, for some assumed thickness, it would be a great boon to him to be able at once to increase or reduce the weight of the same to suit conditions, without resorting to a new set of figures. If such a thing is to weigh 10 per cent. less than it "comes out," then a gauge off from the thickness of the plates will surely accomplish the reduction. If a purchaser desires an article of sheet iron to be of a certain gauge, when its weight of another gauge is known, the transformation becomes easy. For the transformation of weights of wire of given lengths, but varying gauges, the same simple reduction of tenth, or increase of ninth, parts follows; only there are two *successive* reductions or increases to be made for each number in place of one, as the areas of sections of wire vary as the squares and not as the diameters, and we take $(\frac{9}{10})^2$, as the difference of each step of weight of wire.

It must not be supposed that any system will divest the computer in metal work from the use of tables and long lines of decimals. The relation of weights of various metals to their volume is not to be expressed in units. A cubic decimetre of water weighs 1 kilogramme, but a cubic decimetre of iron weighs, sometimes, 7·7694 kilogrammes. No system can simplify this relationship. An inch thick of iron 1 foot square weighs 40·4167 lbs. Were this simplified by making a special pound weight to 40 lbs., even then a plate of iron, $\frac{13}{64}$ in thickness, has not a very convenient arrangement of decimals for its weight per square foot. Expressing thicknesses in any order of figures that may be taken, will not eliminate the long rows of tabular values which must follow the incompatible data needed in practice. But if the proportions of thickness and diameter of commercial and usual sheets and wire are made uniform in the first place, and then have simply related values, such values can be used in computation of the tables, and the relative proportions can be applied to results obtained from the tables.

One more advantage may follow the introduction of a decimal gauge as here described. There exists an absolute necessity for such a gauge, with its exponential in place of arithmetic notation. That such a gauge can be made to become uniform in all nations, the adjustment of the unit to the metric system may offer some inducement to other countries. The Birmingham unit of 0·34 of an inch is purely arbitrary, and out of agreement with any unit of measurement, English or foreign, while the proposed unit of a centimetre = 0·3937 of an inch, gives a standard which is admitted in all lands. If this decimal gauge can be made a universal measure for sheet metal all over the world, it will then have accomplished an end second only in importance to its practical application to the wants of the workmen of England and America.

NOTE.—The foregoing paper appears at this time as the result of an inquiry by Prof. Hilgard, of the U. S. Coast Survey, from the writer about two months since: "What do you know about wire gauges?" The answer then given was that I had examined the subject quite fully many years, 20 or more, since, and had reached conclusions satisfactory to myself, at least, among which were: that they were a necessity to the sheet metal or wire maker, dealer or worker; that the thicknesses indicated by the numbers should vary proportionately by a common ratio, and not arithmetically by constant difference; that the value of the common ratio should be a simple one,



D. A. PARTRIDGE, PHOTO-LITH. 9 S SEVENTH ST. PHILA.

Table I.

Comparison of Decimal, Birmingham & American Wire Gauges.

Dimensions in English Inches, with Corresponding Dimensions for Decimal Gauge in Centimetres

No. of Gauge.	Decimal Gauge. Centimetres.	Decimal Gauge. Inches.	Birmingham Gauge. Inches.	American Gauge. Inches.
0000 = —3	1·3717	0·5401	0·454	0·46
000 = —2	1·2346	0·4861	0·425	0·4096
00 = —1	1·1111	0·4375	0·38	0·3649
0 = 0	1·	0·3937	0·34	0·3249
1	0·9	0·3543	0·3	0·2893
2	0·81	0·3189	0·284	0·2576
3	0·729	0·2870	0·259	0·2942
4	0·6561	0·2583	0·238	0·2043
5	0·5905	0·2324	0·22	0·1819
6	0·5314	0·2092	0·203	0·1620
7	0·4883	0·1883	0·18	0·1443
8	0.4305	0·1695	0·165	0·1285
9	0·3874	0·1525	0·148	0·1144
10	0·3487	0·1373	0·134	0·1019
11	0·3138	0·1236	0·12	0·09074
12	0·2824	0·1112	0·109	0·08081
13	0·2542	0·10008	0·095	0·07196
14	0·2288	0·09007	0·083	0·06408
15	0·2059	0·08106	0·072	0·05707
16	0·1853	0·07296	0·065	0·05082
17	0·1668	0·06566	0·058	0·04526
18	0·1501	0·05309	0·049	0·04030
19	0·1351	0·05318	0·042	0·03589
20	0·1216	0·04787	0·035	0·03196
21	0·1094	0·04307	0·032	0·02846
22	0·09848	0·03877	0·028	0·02535
23	0·08863	0·03489	0·025	0·02257
24	0·07977	0·03140	0·02	0·02010
25	0·07179	0·02864	0·018	0·01790
26	0·06461	0·02544	0·016	0·01594
27	0·05815	0·02289	0·014	0·01419
28	0·05233	0·02066	0·013	0·01264
29	0·04710	0·01854	0·012	0·01126
30	0·04239	0·01669	0·010	0·01003
31	0·03815	0·01502	0·009	0·008928
32	0·03434	0·01351	0·008	0·007950
33	0·03090	0·01217	0·007	0·007080
34	0·02781	0·01095	0·005	0·006304
35	0·02503	0·009856	0·004	0·005614
36	0·02253	0·008870		0·005000
37	0·02028	0·007983		0·004453
38	0·01825	0·007185		0·003965
39	0·01642	0·006466		0·003531
40	0·01478	0·005819		0·003144

Table II.

Weight of One Square Foot of Sheet Metal, or One Foot in Length of Wire, of Thicknesses or Diameters given by the Decimal Gauge; English Units.

No. of Gauge.	Thickness or Diameter.	One square foot of sheet metal.				One foot in length of wire.			
		Iron, pounds.	Steel, pounds.	Copper, pounds.	Brass, pounds.	Iron, pounds.	Steel, pounds.	Copper pounds.	Brass, pounds.
—3	0·5401	21·8277	22·0460	24 4650	23·1148	0·76359	0·77926	0·88290	0·85052
—2	0·4861	19·6449	19·8413	22·0185	20·8033	0·61851	0·63120	0·71515	0·68892
—1	0·4375	17·6804	17·8572	19·8167	18·7230	0·50099	0·51127	0·57927	0·55803
0	0·3937	15·9124	16·0715	17·8350	16·8507	0·40580	0·41413	0·46921	0·44300
1	0·3543	14·3211	14·4643	16·0515	15·1656	0·32870	0·33545	0·38006	0·35883
2	0·3189	12·8890	13·0178	14·4463	13·6490	0·26624	0·27171	0·30785	0·29066
3	0·2870	11·6001	11·7161	13·0017	12·2841	0·21566	0·22009	0·24936	0·23543
4	0·2583	10·4401	10·5445	11·7015	11·0557	0·17468	0·17827	0·20198	0·19070
5	0·2324	9·3961	9·4901	10·5313	9·9501	0·14150	0·14440	0·16360	0·15446
6	0·2092	8·4565	8·5411	9·4782	8·9551	0·11461	0·11696	0·13252	0·12512
7	0·1883	7·6108	7·6869	8·5304	8·0596	0·09283	0·09474	0·10734	0·10134
8	0·1695	6·8498	6·9182	7·6774	7·2536	0·07520	0·07674	0·08695	0·08209
9	0·1525	6·1648	6·2264	6·9096	6·5283	0·06091	0·06216	0·07043	0·06649
10	0·1373	5·5483	5·6037	6·2187	5·8755	0·04934	0·05035	0·05705	0·05386
11	0·1236	4·9935	5·0434	5·5967	5·2879	0·03996	0·04078	0·04621	0·04363
12	0·1112	4·4941	4·5400	5·0371	4·7591	0·03237	0·03303	0·03743	0·03534
13	0·10008	4·0447	4·0851	4·5334	4·2832	0·02622	0·02676	0·03032	0·02862
14	0·09007	3·6402	3·6760	4·0801	3·8549	0·02124	0·02167	0·02456	0·02318
15	0·08106	3·2762	3·3090	3·6721	3·4694	0·01720	0·01756	0·01989	0·01878
16	0·07296	2·9486	2·9781	3·3048	3·1225	0·01393	0·01422	0·01611	0·01521
17	0·06566	2·6537	2·6822	2·9744	2·8102	0·01129	0·01152	0·01305	0·01232
18	0·05909	2·3884	2·4123	2·6769	2·5292	0·009142	0·009330	0·01057	0·009980
19	0·05318	2·1495	2·1710	2·4092	2·2763	0·007405	0·007557	0·008562	0·008084
20	0·04787	1·9346	1·9539	2·1683	2·0487	0·005998	0·006121	0·006935	0·006548
21	0·04307	1·7411	1·7585	1·9515	1·8438	0·004858	0·004958	0·005618	0·005304
22	0·03877	1·5670	1·5827	1·7563	1·6594	0 003935	0·004016	0·004550	0·004296
23	0·03489	1·4103	1·4244	1·5807	1·4935	0·003188	0·003253	0·003686	0 003480
24	0·03140	1·2693	1·2820	1·4226	1·3441	0·002582	0·002635	0·002985	0·002819
25	0·02864	1·1423	1·1537	1·2804	1·2097	0·002091	0·002134	0·002418	0·002283
26	0·02544	1·0281	1·0384	1·1523	1·0887	0·001694	0·001729	0·001959	0·001849
27	0·02289	0·9253	0·9346	1·0371	0·9799	0·001372	0·001400	0·001587	0·001498
28	0·02060	0·8328	0·8411	0·9334	0·8819	0·001111	0·001134	0·001285	0·001213
29	0·01854	0·7495	0·7570	0·8401	0·7937	0·0009003	0·0009188	0·001041	0·0009828
30	0·01669	0·6745	0·6812	0·7560	0·7143	0·0007292	0·0007442	0·0008432	0·0007961
31	0·01502	0·6071	0·6132	0·6804	0·6429	0·0005907	0·0006028	0·0006830	0·0006448
32	0·01351	0·5464	0·5519	0·6124	0·5786	0·0004785	0·0004883	0·0005532	0·0005223
33	0·01217	0·4917	0·4966	0·5512	0·5207	0·0003876	0·0003955	0·0004481	0·0004231
34	0·01095	0·4426	0·4470	0·4960	0·4687	0·0003139	0·0003204	0·0003630	0·0003427
35	0·009856	0·3983	0·4023	0 4464	0·4218	0·0002543	0·0002595	0·0002940	0·0002776
36	0·008870	0·3585	0·3621	0·4018	0·3796	0·0002060	0·0002102	0·0002381	0·0002248
37	0·007983	0·3226	0·3258	0·3616	0 3417	0·0001668	0·0001702	0·0001929	0·0001821
38	0·007185	0.2904	0·2933	0·3255	0·3075	0·0001351	0·0001379	0·0001562	0·0001475
39	0·006466	0·2613	0·2639	0·2929	0·2767	0·0001095	0·0001117	0·0001266	0·0001195
40	0·005819	0·2352	0·2376	0·2636	0·2491	0·00008866	0·00009048	0·0001025	0·00009678
Specific Gravity.		7·769	7·847	8·708	8·228	7·6893	7·847	8·891	8·394
Weight per cu. ft.[1]		485	489·85	543·6	513·6	480	489·85	555	524
Weight per cu. in.		0·28067	0·28348	0·3146	0·2972	0·2807	0·2836	0·3212	0·3033
Weight 1 ft. long, 1 in. round.		2·6453	2·6717	2·95	2·8012	2·6180	2·6717	3·0283	2·8580

[1] These figures for weight per cubic foot were adopted from Trautwine.

Table III.

Weight of One Square Metre of Sheet Metal, or One Metre in Length of Wire, of Thicknesses or Diameters given by the Decimal Gauge; Metric Units.

No. of Gauge.	Thickness or Diameter. Centimetres.	One square metre of sheet metal.				One metre in length of round wire.			
		Iron, Kilos.	Steel, Kilos.	Copper, Kilos.	Brass, Kilos.	Iron, Kilos.	Steel, Kilos.	Copper, Kilos.	Brass, Kilos.
—3	1·3717	106·576	107·643	119·453	112·860	1·13637	1·04373	1·31391	1·24054
—2	1·2346	95·9185	96·8777	107·508	101·574	0·92046	0·93935	1·06427	1·00484
—1	1·1111	86·3267	87·1900	96·7568	91·4170	0·74557	0·76088	0·86206	0·81392
0	1·	77·6940	78·4707	87·0811	82·2753	0·60391	0·61631	0·69827	0·65928
1	0·9	69·9246	70·6238	78·3730	74·0478	0·48917	0·49921	0·56560	0·53401
2	0·81	62·9321	63·5614	70·5357	66·6430	0·39623	0·40436	0·45813	0·43255
3	0·729	56·6389	57·2053	63·4821	59·9787	0·32094	0·32753	0·37109	0·35037
4	0·6561	50·9750	51·4847	57·1339	53·9808	0·25997	0·26530	0·30058	0·28380
5	0·5905	45·8775	46·3463	51·4205	48·5827	0·21057	0·21489	0·24347	0·22988
6	0·5314	41·2898	41·7027	46·2784	43·7244	0·17056	0·17406	0·19721	0·18620
7	0·4883	37·1618	37·5334	41·6506	39·3520	0·13816	0·14099	0·15974	0·15082
8	0·4305	33·4447	34·7891	37·4855	35·4168	0·11191	0·11420	0·12939	0·12216
9	0·3874	30·1002	30·4012	33·7370	31·8751	0·090644	0·092504	0·10481	0·098953
10	0·3487	27·0901	27·3610	30·3633	28·6876	0·073422	0·074929	0·084894	0·080152
11	0·3138	24·3810	24·6248	27·3270	25·8188	0·059472	0·060692	0·068764	0·064923
12	0·2824	21·9429	22·1623	24·5945	23·2369	0·048172	0·049161	0·055699	0·052588
13	0·2542	19·7486	19·9461	22·1349	20·9132	0·039019	0·039820	0·045116	0·042596
14	0·2288	17·7737	17·9514	19·9214	18·8219	0·031606	0·032254	0·036544	0·034503
15	0·2059	15·9963	16·1563	17·9293	16·9397	0·025601	0·026126	0·029601	0·027947
16	0·1853	14·3967	14·5407	16·1364	15·2457	0·020736	0·021162	0·023977	0·022637
17	0·1668	12·9570	13·0866	14·5228	13·7211	0·016797	0·017141	0·019421	0·018336
18	0.1560	11·6613	11·1779	13·0705	12·3490	0·013605	0·013885	0·015731	0·014852
19	0·1351	10·4952	10·6002	11·7634	11·1141	0·011020	0·011246	0·012742	0·012031
20	0·1216	9·4457	9·5402	10·5871	10·0026	0·008926	0·009110	0·010321	0·009745
21	0·1094	8·5011	8·5861	9·5284	9·0022	0·007230	0·007374	0·008360	0·007893
22	0·09848	7·6510	7·7277	8·5756	8·1020	0·005857	0·005977	0·006772	0·006393
23	0·08863	6·8859	6·7548	7·7180	7·2918	0·004744	0·005379	0·005485	0·005179
24	0·07977	6·1973	6·2593	6·9462	6·5626	0·003843	0·004841	0·004443	0·004195
25	0·07179	5·5776	5·6336	6·2516	5·9064	0·003112	0·003176	0·003599	0·003398
26	0·06461	5·0199	5·0700	5·6264	5·3157	0·002521	0·002573	0·002915	0·002752
27	0·05815	4·5179	4·5631	5·0638	4·7842	0·002042	0·002084	0·002361	0·002229
28	0·05233	4·0661	4·1068	4·5574	4·3058	0·001654	0·001688	0·001912	0·001806
29	0·04710	3·6595	3·6961	4·1017	3·8752	0·001340	0·001367	0·001549	0·001463
30	0·04239	3·2936	3·3265	3·6915	3·4877	0·001085	0·0011075	0·001255	0·001185
31	0·03815	2·9642	2·9938	3·3223	3·1389	0·0008790	0·0008971	0·0010164	0·0009596
32	0·03434	2·6678	2·6945	2·9901	2·8251	0·0007120	0·0007266	0·0008233	0·0007773
33	0·03090	2·4010	2·4250	2·6911	2·5425	0·0005767	0·0005886	0·0006669	0·0006296
34	0·02781	2·1609	2·1825	2·4220	2·2883	0·0004204	0·0004767	0·0005402	0·0005100
35	0·02503	1·9448	1·9642	2·1798	2·0595	0·0003784	0·0003862	0·0004375	0·0004131
36	0·02253	1·7504	1·7679	1·9618	1·8535	0·0003065	0·0003128	0·0003544	0·0003346
37	0·02028	1·5753	1·5911	1·7656	1·6682	0·0002483	0·0002534	0·0002871	0·0002710
38	0·01825	1·4178	1·4320	1·5891	1·5013	0·0002011	0·0002052	0·0002325	0·0002195
39	0·01642	1·2760	1·2888	1·4302	1·3512	0·0001629	0·0001662	0·0001883	0·0001778
40	0·01478	1·1484	1·1599	1·2871	1·2161	0·0001319	0·0001346	0·0001526	0·0001440
Specific Gravity.		7·769	7·847	8·708	8·228[1]	7·6893	7·847	8·891	8·394[1]

[1] Value of specific gravity of brass sheets or wire dependent on the composition of brass.

etc., etc. After setting forth the scheme, and preparing an illustration of it graphically, as shown on the plate, its publication, as a matter of public interest, was advised by Prof. Hilgard. While going to press, I have been favored by the Professor with a copy of a communication addressed to him on October 26th, from the Department of Standards, Board of Trade, England, asking if there is any official gauge or standard measure in the United States for wire and sheet metals, and whether more than one gauge is used by manufacturers in America; and saying that in the German Empire there is some agitation for the establishment of a better gauge than the Birmingham or Dilhingen gauges now in use, and adverting to the *unsatisfactory* Birmingham gauge now in use in England. From all this it would appear that the present time is auspicious for the consideration of the subject of the paper in this and other countries.

A NEW SINE PENDULUM.

By Thomas William Tobin, Professor of Physics and Chemistry, Central University, Richmond, Kentucky.

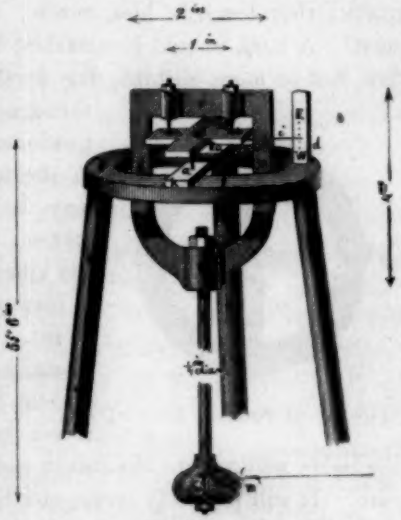
Having occasion to illustrate the properties of motion in my department of instruction, it occurred to me, as no doubt it has occurred to others, that the pendulum afforded many practical advantages usually overlooked in general illustrations. This, coupled with the fact that one of my brother professors, L. G. Barbour, was about to introduce the celebrated Foucault experiment as a lecture illustration, suggested to my mind the following instrument. I have worked at it with a degree of devotion which can only be repaid by the gratification afforded in the revelation of natural laws, and, I think, brought an instrument to a state of completion fitted for the use of those who, like myself, are engaged in scientific education. To such I present freely the results of these labors, in the hope that they may be the means of affording as much pleasure as I experienced in their pursuit:

Description of the Instrument.

The following description and drawing is intended to record the apparatus used in actual experiments, and which, having given satis-

factory results, I prefer to adopt rather than embody any improvements or additions which I would introduce in constructing another instrument. Such improvements or additions I will, however, record, leaving their incorporation discretionary on the part of the future manufacturer.

The pendulum is constructed of steel-rod, $\frac{1}{4}$ in. in diameter, and measuring, from the points of support to the extreme lower end, 5 ft. 6 ins.; it is tightly screwed together, so that the parts are compact; indeed, the whole instrument, when set up, must be in similar condition—firm and rigid in all its parts. There are two steel points, hardened and polished, at *b* and *b*, with adjustable check screws. When the pendulum is suspended from these points in perfect equilibrium, they must be in a truly horizontal plane; this condition is indispensable in obtaining accurate results. The pendulum is supported upon, but in no way attached to, a cross-piece, *g*, made of hardened steel or brass, having four agate cups equally distant from its centre. These cups are accurately ground and polished and set, two into the upper surface of two opposite arms, and two in the under surface of the other arms, in such a manner that the crowns or extremities of the sinkings of all four cups are in the same plane. Below this is an oblong piece of steel, *k*, having two adjustable polished steel points, *a*, *a*, of like construction to those in the pendulum-head, and corresponding to the lower surface agate cups, in *g*, to receive them. Thus fitted together, the whole is supported upon a strong tripod with a circular opening, as shown. Attached to the cross-piece, *g*, at the extreme corner of the right arm, is an index, *i*. A scale, *d*, is mounted upon the tripod; this scale may be divided in ·01 of an inch, or other convenient units.



Front View.

To adjust the pendulum, it should be mounted as shown in the drawing, all the parts being leveled, and whatever plane the pen-

dulum is started in, that plane must be preserved by it without variation. Should the vibration become elliptical, the cause may be found in imperfect mounting. Before actual use it may be started in a circular direction, and if that quality of rotation is preserved, the indication points to perfect equilibrium of the parts. Should it, however, degenerate into a lineal motion, then the points parallel with the plane of oscillation will probably be found imperfect. Any quality of vibratory motion ought to be preserved for at least twelve hours.

Having the parts in perfect order, the instrument may be started. It does not matter in which position the plane of vibration is situated, but, for reference, the following is suggested. The observer standing in front of the instrument, the opposite direction may be called north; that towards him, south; the right hand, east; and left, west. A hook should be attached firmly to an adjoining wall, about five feet or more distant, due north, and a thin silk cord passing through the hook and attached to the pendulum at *m*, the other end being held in the hand of the observer. This cord may be detached when the ball is in motion, without disturbing the quality of the vibration.

Plan.

Now upon pulling the cord gently about 2 ins., and waiting until all incidental vibration has ceased, it may be loosed, and the index marked. If the instrument is set exactly in the plane of vibration, the index will remain absolutely stationary; but this is seldom the case. It will probably move, and the movement must be noted. If the index moves east on the scale, while the pendulum is north, then the plane of vibration is east of north. The entire pendulum may be moved, by means of the plate, *k*, upon the tripod in a northeast direction. I would recommend a tangent screw for this purpose, but have not as yet used one, and, therefore, it is not shown in the drawing. If the index points west, while the pendulum is north, the plate, *k*, will of course have to be moved northwest, to bring it to a normal condition. These movements are of a very delicate nature, and require skill and patience in adjustment.

Having arranged the instrument so that upon starting the pendulum gently, the index remains perfectly still, the silk cord may then be detached by carefully lifting it off the hook, *m*, and the time noted. Vibrations of the index will become apparent in from one to two minutes; their value for the hourly motion of the earth, is estimated by the formula given as under.

Instead of the index a small mirror may be attached to the cross-piece, *g*, and, by means of a lamp, a spot of light reflected to a distance of several feet or more, and thus giving the indications greater amplitude. I would prefer a heavier pendulum-ball than that used hitherto, and a longer rod, say 6 ft., instead of 5 ft. 6 ins. The points of support might also be made nearer together, probably $\frac{1}{2}$ in. instead of 1 in., with advantage.

Formula.

If a physical pendulum be constructed capable of vibrating in one plane only, and this plane caused to revolve, the following results ensue:

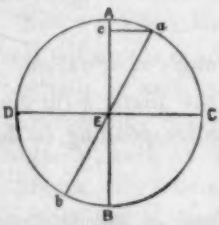


Fig. 1.

In Fig. 1, let *A B* represent such plane, and in which the pendulum is started. On revolving the plane to *C D*, the pendulum will stop, or the vibrations be reduced to zero. At any intermediate position, as *a b*, the value of original vibration is represented by the component *c E*, being diminished by the component *a c*. Hence, the value of a vibration of one plane is represented by the cosine of the angle of deviation from the original plane of oscillation.

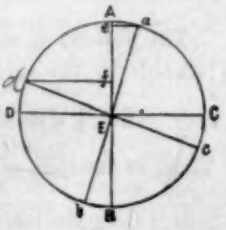


Fig. 2.

Now if a pendulum is free to vibrate in two planes only, at right angles, and these planes capable of revolving, as *A B*, *C D*, Fig. 2, starting the pendulum in the direction *A B*, and revolving the planes to *a b*, *c d*, the value of the original vibration is, in *a b*, as cosine *e E*, and, in *c d*, as cosine *f E;* or, inversely, as the sines *e a* and *f d*. Hence, in planes at right angles, the values of a vibration to the two planes are directly as the cosines of the angles of deviation from starting, and inversely as their sines.

In the sine pendulum already described, any deviation from the original plane, *A B*, in which the pendulum is started, is, therefore, shown by the sine, as *e a*, of the angle of deviation. The movement of the index shows this quantity from a state of rest, and, therefore, twice this quantity in a complete vibration.

As it is convenient to have the index shorter than the length of the pendulum, the ratio of their lengths involves a proportion; or, P representing the length of the pendulum; I, the length of the index; i, the indication of index; v, the length of entire vibration of pendulum; and d, the angle of deviation; we have:

$$P : I :: i : v, 2 \sin d; \text{ or,}$$

$$2 \sin d = \frac{Ii}{Pv}.$$

When the index is the same length as the pendulum, the equation is simplified thus:

$$2 \sin d = \frac{i}{v}; \text{ or,}$$

the indication of index = twice the sine of the angle of deviation.

These statements may be verified by turning the plate, *k* (in diagram), about its central axis, through an angle corresponding to the above sine.

To find the angle of deviation of the pendulum, in any latitude, during a given time. (By Professor L. G. Barbour.)

The following simple equation will serve to verify the results obtainable by the sine pendulum, indicating the rotation of the earth:

$$\text{Sin } \tfrac{1}{2} d = \text{sin lat} \times \text{sin } \tfrac{1}{2} \text{ hour angle.}$$

Thus, in latitude of Richmond, Kentucky, 37° 46′ for one hour.

Log sin lat. 37° 46′ = 9·787069
Log sin ½ 15° = 7° 30′ = 9·115698

Log sin ½ angle d = 8·902767

Or, $4° 35' \times 2 = 9° 10' = d.$

THE GRAPHICAL METHOD VERSUS THAT BY LEAST SQUARES.

By Henry L. Abbot.

In some recent articles upon the Method of Least Squares, prepared for the Journal of the Franklin Institute by Professor Merriman, of the Sheffield Scientific School, he has selected, as an example, the mean curve of observation given in "The Physics and Hydraulics of the Mississippi," showing the law of change in velocity from surface to bottom in a vertical plane parallel to the current. By applying the method of least squares to the observations, he has deduced new values for the constants of the formula, which give a rather closer accordance than those determined by the graphical method in the original Report. The absolute differences in the two curves, however, are trifling; the largest, which is more than double any of the rest, being only five-thousandths of a foot per second—a quantity too small to be detected by measurement.

Every mathematician, of course, will admit that the method of least squares is the most accurate of any for fixing the values of the constants in such cases, but I cannot agree with Prof. Merriman in characterizing the graphical method as "very unscientific." In my judgment, each of the two methods has its advantages and its disadvantages, and true science requires that the best selection shall be made for the particular case in hand.

The method of least squares is, so to speak, mechanical. It leaves no scope for judgment on the part of the investigator, and any numerical mistake in the long and tedious computation is not readily detected, and may often vitiate the final result. By the graphical method the mind grasps the whole problem; the eye perceives how each given point of the curve deviates from the general law, and if any of them are more doubtful than the others, their weight can be intelligently regulated. In general, I consider that where the data are exact and sufficient, and the labor of computation is warranted by the importance of the result, the method of least squares should have the preference. In other cases, I should use the graphical method.

In this particular case of the grand mean curve of velocity, the method of least squares can advantageously be applied; and if this

curve had been the only problem of the kind under discussion at the time, preference would naturally have been given to the more exact method.

It is not stated in the report, and it probably did not suggest itself to Prof. Merriman in considering the matter, that with so many similar curves to discuss, we could greatly abbreviate the labor of the graphical method. The different curves were all plotted on the same scale on accurate section paper, printed from an engraved stone. One general set of parabolas, which, perhaps, required a couple of hours to compute, was plotted on a piece of tracing paper, with a common vertex. By placing this over a plotted set of observations, a parameter, very closely according with the data, could be taken off at sight. Starting with this, the labor of fitting the curve to the observations was neither excessive nor tedious, and any error of computation was at once detected. Having become habituated to this method, it was naturally used in framing the final equation of the grand mean curve; although in this case it might probably have been better to use the method of least squares. The two results, however, as already stated, do not differ within the limits of measurement.

That we derived great assistance from the general use of the graphical method is incontestable, and I think this will be the experience of any investigator who gives it a fair trial. By no other method are the results so vividly presented to the mind at every step of the study. Indeed, a foreign writer, after discussing many of the old observations made upon the rivers of Europe, and showing graphically that they accord, in a surprising degree, with our new subsurface theory, attributes the failure to discover the law from them to the fact that they had been discussed by a purely mathematical, and not by the graphical, method. The expression, "very unscientific," seems, therefore, rather too sweeping.

I will add that it is a matter of regret that the slight numerical error, in the formula pointed out by Prof. Merriman, had not been discovered before the second edition of "The Physics and Hydraulics of the Mississippi" passed through the press. It should be, as he suggests:

$$V = -0{\cdot}79222\, d_{11}^{\,2} + 3{\cdot}2600,$$

instead of

$$V = -0{\cdot}79222\, d_{11}^{\,2} + 3{\cdot}2611.$$

TENACITY OF METALS AT VARIOUS TEMPERATURES.

Results of a series of experiments recently made in Portsmouth dockyard, with the view of ascertaining what loss of strength and ductility takes place in gun-metal compositions when raised to high temperatures.

The object of making these experiments was to see whether gun-metal would be more or less suitable than cast iron, for making such articles as stop and safety valve boxes, steam pipe connections, fastenings, etc., which might be subjected to high temperatures, either from superheated steam or from being placed in proximity to hot uptakes or funnels. The result of these experiments shows that it is desirable to make further investigations on this important subject. The method adopted for heating the specimens was an oil bath, near the machine for breaking them, the specimens were suspended in the oil out of contact with the vessel containing it, and the dies for gripping them were also so heated; the process of fixing and breaking occupied about one minute, during which care was taken to prevent, as far as possible, loss of heat by radiation and conduction. The recorded temperatures are those of the oil when the specimens were taken out.

In the case of gun-metal, three or more tests were made at each temperature, and the results recorded in the table are the mean, except in a few cases affected by defects in the metal. All the specimens of each composition were run from the same pot in the same manner, *i. e.*, in a horizontal position with a head of 2½ in. to secure uniformity, except those in columns 1 and 2, which were purposely cast separately. It will be observed that those in No. 2 were stronger at the atmospheric temperature than No. 1, and that they suffer sooner by increases of temperature. It may be observed that all the varieties of gun-metal suffer a gradual, but not serious, loss of strength and ductility up to a certain temperature, at which, within a few degrees, a great change takes place, the strength falls to about one-half the original, and the ductility is wholly gone. At temperatures above this point, up to 500 deg., there is little, if any, further loss of strength; the precise temperature at which this great change and loss of strength takes place, although uniform in the specimens

cast from the same pot, varies about 100 deg. in the same composition at different temperatures, or with some varying conditions in the foundry process. The precise temperature at which the change took place in No. 1 series was ascertained to be about 870 deg., and in that of No. 2 at a little over 250 deg. Whatever may be the cause of this important difference in the same composition, the fact stated may be taken as quite certain. The possibility of such a change taking place at a temperature so low in the best gun-metal, used for the more important parts of machinery and boiler mountings, is so important that the point was most carefully tested by repeated experiments at the same temperature, both sorts being heated at the same time in the bath.

Phosphor bronze, the only metal in the series which, from its strength and hardness, could be used as a substitute, was less affected by temperature, and at 500 deg. retains more than two-thirds of its strength and one-third its ductility; when this metal was tested, nothing was known of the difference which may arise from variations in the process of casting, or difference in the quality of the material used, shown in gun-metal, and before adopting it as a substitute for gun-metal this point should be tested for phosphor bronze; and also whether it is possible to harden any of the other compositions without loss of strength.

Rolled Muntz metal and copper are satisfactory up to 500 deg., and may be used as securing bolts with safety.

Wrought irons, Yorkshire and re-manufactured, increase in strength up to 500 deg., but lose slightly in ductility up to 300 deg., where an increase begins and continues up to 500 deg., where it is still less than at the ordinary temperature of the atmosphere. The strength of Landore steel is not affected by temperature up to 500 deg., but its ductility is reduced more than one-half.—*Engineer.*

This is a very important investigation, and the Admiralty deserves much credit for undertaking it, but it is to be regretted that so inexact a method was employed in determining the temperatures.

While the recorded temperatures may approximate sufficiently near the exact ones, for the mere comparison of the specimens used in these experiments, yet the uncertainty as to the loss of heat during the time required for fixing and breaking, introduces an error which will prevent a strict comparison between these and other experiments.

Tenacity of Various Metals at Different Temperatures up to 500 Deg. Fahr.—Constant of Machine, 50·25.

Temperature.	Gun-Metal Rods, 1 in. Diameter.												Phosphor Bronze Rods, 1 inch Diameter Cop., 92·5 Tin, 7· Phos., ·5		Muntz Metal Rods, 74 inch Diameter. Cop., 62· Zinc, 38·		Copper Rods, ·72 inch Diameter.		Cast Iron Rods, 1 inch in Diameter. Welsh, ·25 Scotch, ·25 Scrap, ·5		Wrought Iron.				Landore Steel Strips, ·74 inch by ·49 inch.	
	1. Copper, 87·75 Tin, 9·75 Zinc, 2·5		2. 2d set. Copper, 87·75 Tin, 9·75 Zinc, 2·5		3. Copper, 91· Tin, 7· Zinc, 2·		4. Copper, 85· Tin, 5· Zinc, 10·		5. Copper, 83· Tin, 2· Zinc, 15·		6. Copper, 92·5 Tin, 5· Zinc, 2·5										Re-manufactured. Rods 74 in. in Diameter.		York-shire. Rods ·70 in. in Diameter.			
	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.
Fahr.	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*
Atmospheric deg.	535	12·5	575	8·75	525	16	525	21	485	26	560	29	609	17·5	700	2·5	460	2·5	480	Nil	500	22	460	25	555	26
100	505	10	....	....	525	15·5	550	18	480	26	....	....	614	17	680	2·5	465	2.5	423	"	530	18.75	460	24.25		
150	525	11	....	....	525	14	530	19·5	450	25·5	....	....	610	18	720	3·9	445	4	441	"	530	15				
200	485	10	535	8·75	460	9	523	19	460	26·25	440	11	605	18	685	3·9	440	5	440	"	530	15	465	17·25	535	22·5
250	505	10	385	5	255	3	515	16	440	26	360	6	580	15	670	5	430	7	470	"	540	15				
300	500	10	295	·66	265	Nil	531	18·25	435	23	255	.66	575	12	650	2·5	430	6	490	"	650	15·5	480	7·5	555	11·25
350	450	8·25	295	Nil	....	....	495	17	435	25	....	....	470	7	650	2·25	430	6	470	"	660	12·5				
400	245	·75	....	....	260	Nil	260	2	435	25	....	....	424	5	600	2·25	420	6	401	"	640	12	465	15	590	10·25
450	265	Nil	....	....	....	....	250	2	152	1·2	....	....	380	4	615	3·75	415	6	400	"	680	15				
500	250	"	....	....	275	Nil	230	2	152	Nil	....	....	420	5	620	5	390	6	400	"	680	29	550	13·75	600	10

* In a length of 10in.

How Phonography in Audatype is Produced.
D.S.H.

AUDATYPE FOR PRINTING PHONOGRAPHY, AS PRODUCED BY PHOTO-RELIEF PROCESSES.[1]

By D. S. Holman.

In printed phonography there should be found as few as possible of the characteristics of individual handwriting. The forms of the words should be geometrically true, so as to serve as a correct guide for the reader. A description of the means by which this desired end can be accomplished, will be of interest to those who are anxious for a diffusion of a knowledge of the art of phonetic shorthand.

Before proceeding, however, to give a description of these methods, it may be well to allude to some of the ways in which phonography has heretofore been printed. The printing has usually been done by means of transfer lithography; but this has not been satisfactory, for the reason of its resemblance to handwriting. To remedy this, a number of attempts have been made to engrave phonography on metal and stone; but, although the quality of the work so done has been good, the expense has been so great that the amount of reading matter thus produced has been limited. Probably the best engraved phonography was that produced by Mr. Benn Pitman on stone, and which appears in all the books he has published. Another kind of engraving was produced upon copper by Mr. E. Webster, in 1849 to 1852. It was engraved by means of steel punches driven into the copper plates. The writer of this was familiar with this process, having made a set of punches for Mr. Webster, for that purpose. It took 120 punches to make all the combinations necessary to produce the engraved words. Later Mr. Isaac Pitman introduced a beautiful method, which we see now in all his books. We do not know how this is produced, but infer, from the broken lines which now and then are seen in his pages, that it must be produced, in part at least, by means of punches, with which a matrix is made from which the relief plate is obtained.

All these methods thus alluded to are different from the one by which this page, and those which have before appeared in this Journal, have been produced. We now give a description of the

[1] Translation of article printed in audatype on page 428.

methods by which these type plates were produced, and to which we have given the name of audatype.

In the production of these plates, photography plays an important part. It has been found advisable to make the original from which the photograph is taken, much larger than the plate which receives the picture, and for two reasons: First, the defects in the large writing are reduced in proportion as the size is decreased, and second, by the greatly condensed light which is thus brought to bear upon the negative, the lines are made much sharper, and the spaces between them much more opaque than if the negative were made of the same size as the writing. Especial pains must be taken in producing the writing to be reduced. The light lines must be of uniform thickness, and much thicker than can be made by an ordinary pen; and for this work, Holman's audascript pen is especially adapted. The peculiarity of this pen is that it makes a line of uniform width whichever way it is moved. The shades, however, are made by a second tracing with the same pen. This method of shading is similar to that by which Mr. Benn Pitman produces his engraving upon stone: the lines being first engraved of uniform thickness, being afterwards thickened for the shades. It will be evident that to produce the very perfect and beautiful forms in Mr. Benn Pitman's works, it requires much greater skill in the engraver, who must write upon the stone the same size that appears in the print, than to produce the same forms by this process, in which the original is written six or more times as large as it finally appears. The negative can be taken of any size, so as to fit in any publication in which it is desired to have it appear.

There are two methods of producing the type plate from the negative, viz.: the swelled gelatine and the dissolved gelatine processes. Both have been used in the production of the phonography which has appeared in this JOURNAL; the present page being by the dissolved gelatine, or photo-electrotype, process, and all the former pages by the swelled gelatine process.

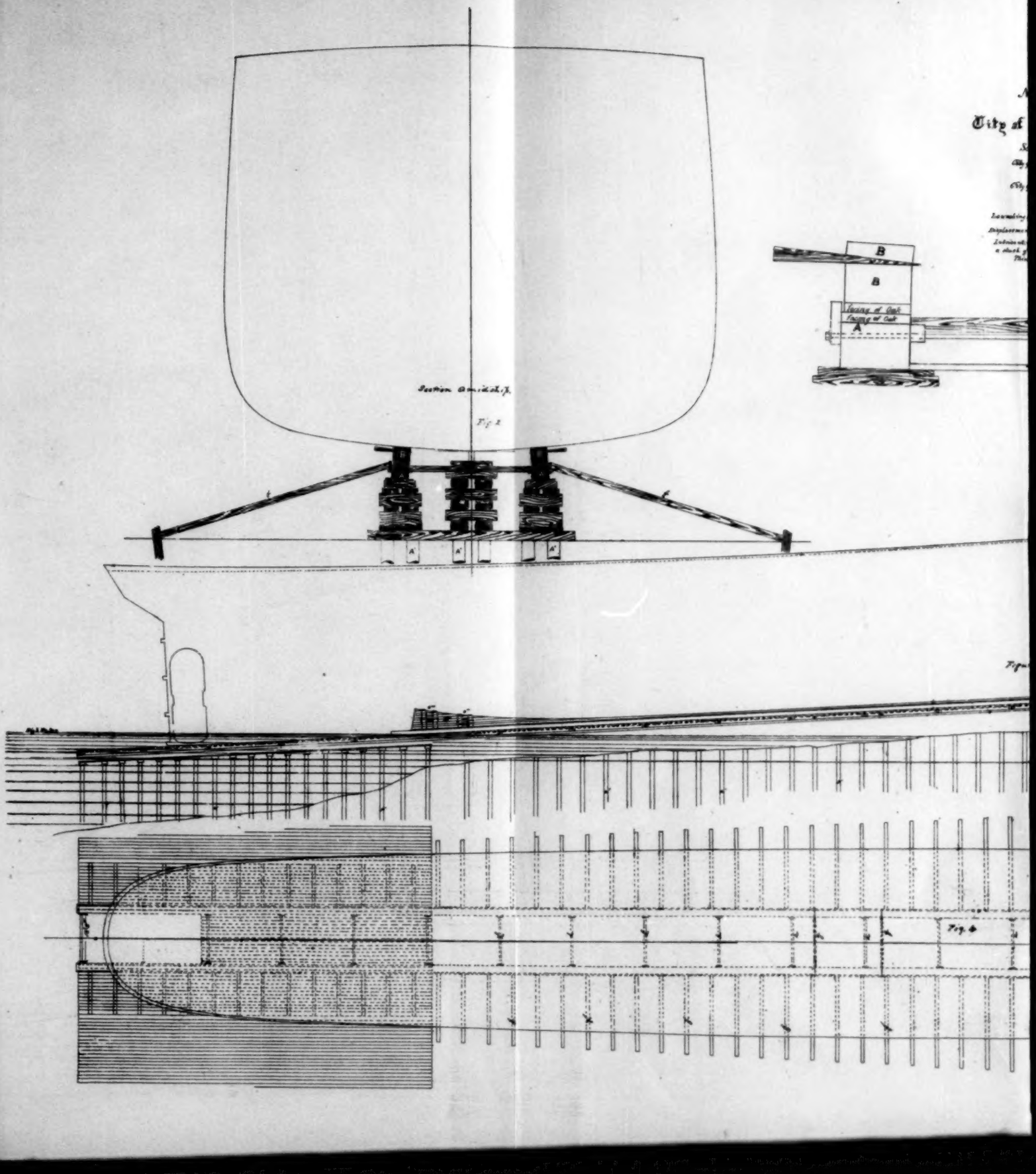
In the latter process, a thick film of bichromatized gelatine is spread on a sheet of glass, and upon this a sun picture of the negative is made, as in ordinary photographic printing. Wherever the light strikes, which in this case is upon the writing, the gelatine becomes insoluble. The gelatine film is then moistened with cold water, which causes the soluble portions between the lines to swell up

and leave the writing sunken. A plaster cast is taken from this, when the writing will appear in a raised line upon the plaster. This cast is then pressed into wax; the wax impression is dusted over with plumbago to give it a metallic conducting surface, and is then placed in a galvanic bath, remaining there from one to three hours, producing an electrotype plate from which the printing is done. It is found, however, that the lines on the plaster cast are not high enough to make a good type, and before pressing the cast into the wax, the spaces between the lines are routed out, or dug out, with a tool, to any required depth. Another method of accomplishing the same result is first to take the wax impression, the workman afterward building up the spaces on the wax, before putting it into the galvanic bath. Still another way is to take a plaster cast from the one already made, which will reverse it, the lines appearing sunken, and from this last cast to make a stereotype plate in type metal, and rout out the spaces in the plate itself from which the printing is done.

The dissolved gelatine, or photo-electrotype, process is somewhat more simple, and is the reverse of the one just described. The film of gelatine is made very much thicker than before. A light sun picture is taken, leaving sharp outlines. The surface is moistened and the gelatine washed out, slightly deepening the spaces between the lines. The film or plate of gelatine is then dried, and these depressions are filled with an opaque paste, and the plate is again exposed to the full glare of the sun, by which the chemical effect of the light upon the lines is intensified and deepened, so that the gelatine is hardened to a considerable depth and a gradually increasing breadth, making a firm foundation for the type. The plate is again washed and the spaces deepened to any extent desired. It is then dried, and can be printed from directly, as a type plate, or electrotyped as before described.

The negative can also be used in connection with the zinc etching process, by which the writing is transferred to a zinc plate, and the spaces between the lines eaten out by acids.

Sea Sounding.—Sir William Thomson has recently patented an ingenious method of sounding, which can be put in practice without reducing a ship's speed. By the wire-sounding apparatus of the same inventor, a great deal of time is saved, owing to the small amount of friction of the sea water on the wire in sinking and in hauling in, as compared with the friction on the rough hemp surface of the lead-line. Owing to the speedy execution of a wire sounding, it was also possible in shallow water to take a series of flying soundings from a ship without slackening her speed as she approached the coast—a great advantage to a mail steamer in thick weather. The new invention of Sir William Thomson measures the depth independently of the wire paid out, which, however, may serve as a check on the other result. The pressure of the sea water at the depth to which the lead sinks, is made the means of registering the depth, in the following way. A glass tube, closed at one end and open at the other, is lined inside with a coloring matter, such as aniline blue, red prussiate of potash, or, better still, chromate of silver, which will be acted upon chemically, and discolored by sea water. This tube, suitably guarded in a brass guard-tube against accidents, is lowered with the lead-line into the sea. The sea water, forcing its way into the tube by the open end, compresses the air-column therein, and mounts up the tube to a height corresponding to the pressure, and discolors the lining of the tube in its passage. The discoloration in the tube marks the height to which the sea water has penetrated, and this becomes a measure of the water pressure, and consequently, by employing a suitable scale, of the depth in fathoms to which the lead was sunk. A chromate of silver lining of the tube is turned from orange yellow to white, by the action of the sea water. Instead of discoloring the lining by sea water alone, the sea water itself may be tinctured by a dye as it enters the tube; or it can be arranged by proper valves simply to trap the water in the tube, and retain it there until it can be brought to the surface and its height read off. The indicator tube and lead-line are used in conjunction with the pianoforte-wire apparatus. Recent trials of this new apparatus on board H. M. S. *Minotaur*, have proved highly satisfactory.—*The Telegraphic Journal.*


B
B
Fig. 2
Fig. 4

J. CARBUTT, Photo-Lith. Phila.

Manner of Launching the Peking & City of Tokio.

Scales 2" & 1" = 1 foot

Ways of Peking { Ways inclined 1" to 1 foot. Rate of ways in 33 seconds.

Ways of Tokio { Ways inclined 1" to 1 foot. Rate of ways in 33 seconds.

	City of Peking	City of Tokio
Draft	Aft ..... 24'	Aft ..... 23'
	Forward .... 24'6"	Forward .... 24'6"
Length	4600 Tons	3560 Tons.

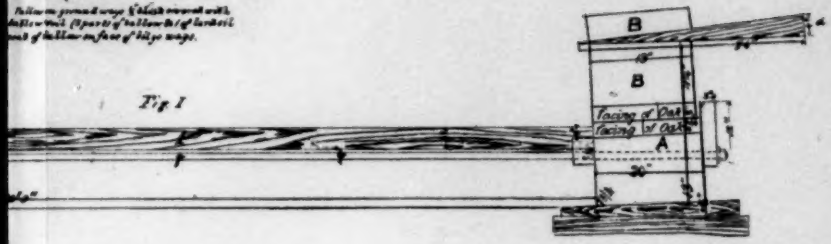
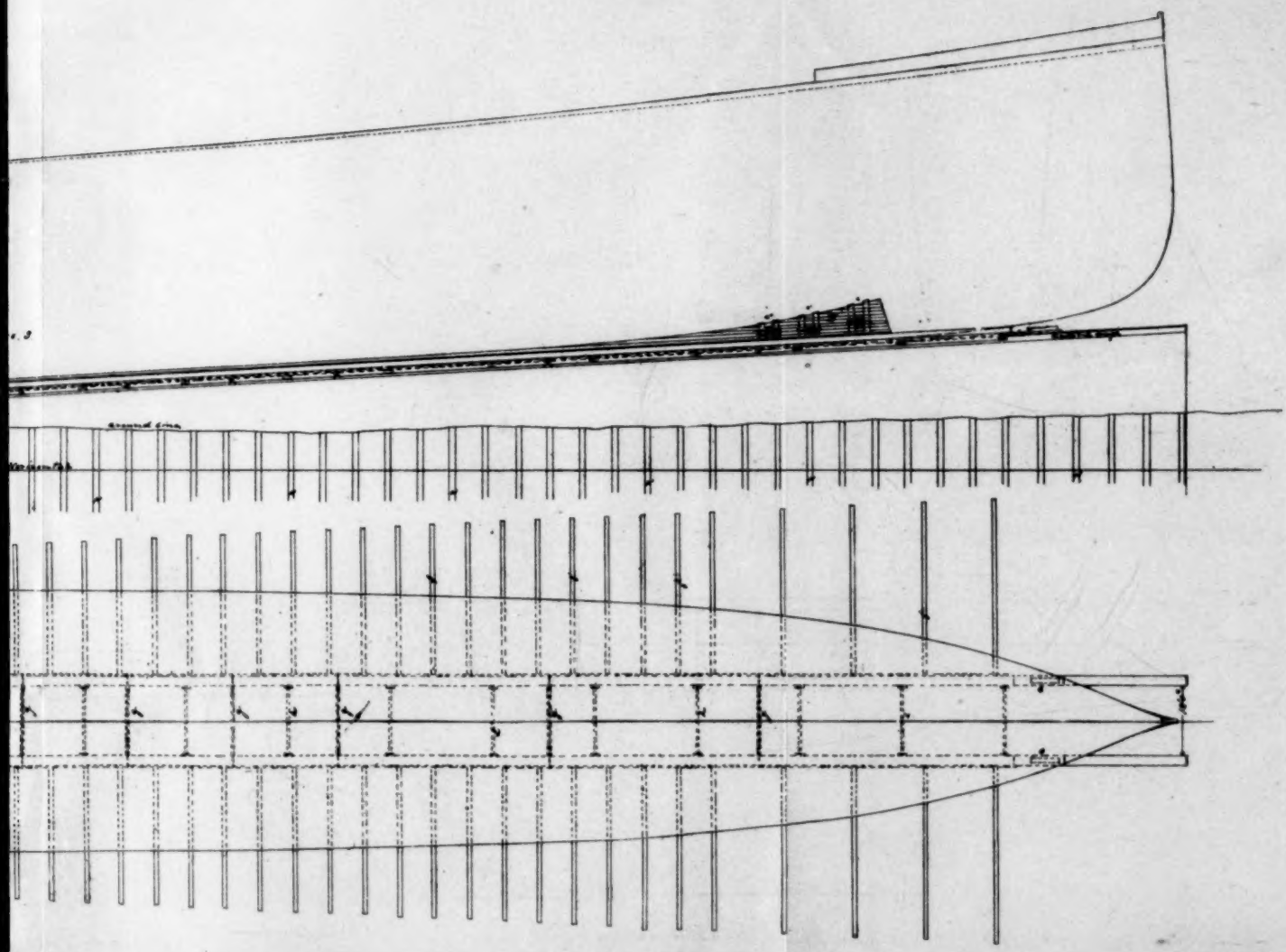



Fig 1